STAFF REPORT

SUPPLY AND COST OF ALTERNATIVES TO MTBE IN GASOLINE

TECHNICAL APPENDICES

Report on the Oxygenate Market:
Current Production Capacity, Future Supply Prospects and Costs Estimates

DECEMBER 1998

CALIFORNIA ENERGY COMMISSION

Pete Wilson, *Governor*

P300-98-013B

Evaluating the Cost and Supply of Alternatives to MTBE in California's Reformulated Gasoline

Project Report
Oxygenate Subcontractor

Task 2: Report on the Oxygenate Market: Current Production Capacity, Future Supply Prospects, and Cost Estimates

Prepared For the California Energy Commission

Under Subcontract No. CM60065W

October 5, 1998

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Section 1 Introduction

1.1

Scenarios and Assumptions

This report covers Task 2 of the Oxygenate Subcontractor activity, detailing the current production capacity for oxygenates, the ability of the oxygenate industry to increase production capacity, and estimated costs for delivery of alternate oxygenates to California.

Within this report, we will assess the current production capacity of the following oxygenates:

MTBE
Ethanol
ETBE
TBA
TAME

Furthermore, this report will assess the costs of supplying each of the various oxygenates to California through various levels of increased Californian demand. The report will also analyze the effect of the various scenarios and policy assumptions specified by the CEC on the delivered price to California.

The scenarios to be analyzed in this study have been defined by the CEC as the following:

I. A reference scenario, in which MTBE continues to be us ed in the California refining industry. All Federal and state regulations regarding the use of MTBE and other oxygenates are presumed to remain in place. The CEC has also specified a slight variation of this reference scenario, in which MTBE continues to be used, but HR 630 (Bilbray bill) is passed, thereby removing the Federal mandate requiring California refiners to supply gasoline to federal non-attainment regions in California.

II. MTBE ban in California

In this scenario, California bans MTBE use in CARB RFG. Within this scenario, six policy assumptions are to be looked at.

A. Current regulations in place: California and Federal regulations regarding gasoline production remain in place and no new regulations are put on the books.

B. HR 630 passes: The Federal mandate requiring California gasoline manufacturers to use oxygen in gasoline is removed.

C. Ethanol RVP Waiver: Gasoline blended with 10% volume ethanol is given a 1 psi RVP waiver. CARB RFG gasoline containing 10% ethanol is thereby allowed to have up to a 8 psi RVP.

D. Tax Credit Ended for Ethanol/ETBE: Federal tax credits granted to ethanol and ETBE are removed.

E. Tax Credit Ended and HR 630 Passes: Combination of policy assumptions B & C.

F. Tax Credit Ended and Ethanol Receives RVP Waiver: Combination of policy assumptions C & D.

III. MTBE ban throughout United States

The policy assumptions for this scenario are the same as the policy assumptions A - F in scenario II (the MTBE ban in California only).

1.2

Supply curves

For each alternate oxygenate, supply curves are provided showing a price/volume relationship for each oxygenate delivered to California under both an MTBE ban in California and an MTBE ban throughout the United States. In addition, a supply curve for MTBE was built for the reference scenario in which MTBE is not banned. Supply curves are considered both for the intermediate term and the long term. The intermediate term is defined as the time period that is long enough to allow the alternative oxygenate for each scenario category to achieve a new equilibrium level, allowing for additions to existing capacity, as long as it does not include grassroots construction (new oxygenate plants). The long term is defined as the time period that is long enough to allow new oxygenate capacity to be built or converted and is associated with a substantial increase in the capital stock of each alternative oxygenate industry.

The assumptions and approaches behind each supply curve are discussed in Sections 4 and 5, and the price/volume relationships are found in various tables in Appendix M. It should be noted that supply curves have not been constructed for each policy assumption. This is because several policy assumptions are expected to have no effect on the *slope* of the supply curves.

For example, the policy assumption of the passage of HR 630 may result in the refinery model choosing a lower volume of ethanol or other oxygenate on the supply curve, but the supply curve itself would not be affected by such legislation. Another example is the policy assumption that ethanol is granted a 1 psi RVP waiver. This would allow ethanol to be used up to 10% of volume in CARB RFG (or 3.5 wt% oxygen), pending new rules that would be required to override California's 2.0 wt% oxygen limit. This may result in the Refinery

Modeler choosing a higher volume of ethanol to be blended in CARB RFG, but the supply curve itself would be unaltered. The removal of ethanol/ETBE tax credits, however, does alter the slope of the supply curves and thus separate curves have been constructed for these policy assumptions.

The “combination” policy assumptions (E & F), which stipulate the removal of the tax credits and either the passage of HR 630 or an RVP waiver for ethanol, do not have separate supply curves. Instead, it is expected the refinery model will utilize the tax credit scenario supply curves and choose volumes on that curve that are consistent with either the removal of the oxygen mandate or the granting of an RVP waiver to ethanol. For each oxygenate, including MTBE, the various capital costs involved in increasing capacity are discussed.

Section 2.

Global Oxygenate Production Capacity and Demand Assessment

This section outlines the current capacity for oxygenates in the U.S. and around the world. A list of all identified oxygenate plants in the world, by nameplate capacity when possible, can be found in Appendix A. This section also specifies volumes of oxygenate capacity that are scheduled to come online in the future. A list of these projects can be also found in Appendix A.

2.1 MTBE

SUPPLY

Global MTBE production capacity currently totals about 523,000 b/d, with plants located in North America, South America, Europe, Asia/Pacific, Eastern Europe, and the Former Soviet Union (FSU).

MTBE production capacity is dominated by North American producers, whose production capacity is 248,000 b/d or nearly 50% of the world total. Western Europe and the Middle East own the next largest segment of world capacity, with facilities totaling 93,000 b/d and 83,000 b/d respectively.

In addition to present capacity, there is an additional 52,000 b/d of capacity around the world that is either currently under construction or in the engineering stage. Most of this capacity will be coming on-line within the next two years. This includes a 19,000 b/d plant in Canada that will have the dual ability to produce MTBE or ETBE.

Building a new refinery-based MTBE plant using C4s from an fluid cat cracker unit would cost about $6,000-$10,000 per daily barrel, and would take an average of 1.5 years to construct. Existing refinery-based MTBE units are feedstock-limited and it is not possible to expand the present capacity of refinery-based ether units, as the isobutylene feedstock is a byproduct of the refinery process and the source of this by-product cannot generally be expanded. However, there are many refineries without MTBE plants that have large enough FCC units to support commercial volumes of MTBE production. There is approximately 2.2 million b/d of FCC capacity in the U.S. without associated MTBE production. Using the benchmark of 1,000 b/d of MTBE production for every 25,000 b/d of FCC capacity, an estimated 87,000 b/d of additional MTBE production could be built at U.S. refineries.

Building a world scale MTBE plant (mixed butanes/dehydrogenation) would cost on the order of $20,000-28,000 per daily barrel and would take 1.5 years to construct. Unlike FCC-based units, butane plants can be expanded. Industry data suggests that expanding plants costs approximately $10,000 per daily barrel.

In addition to 523,000 b/d of present capacity and the 52,000 b/d of capacity either under construction or in the engineering phase, there are several MTBE projects around the world that are more tentative in nature. The total amount of this potential capacity is approximately 112,000 b/d. These projects are either only in the planning stages or little information was available.

DEMAND

MTBE consumption is dominated by the U.S., with demand of about 250,000 b/d. Most MTBE is used to comply with mandated oxygen content rules for gasoline supplied to either RFG or wintertime carbon monoxide areas. A small amount may be utilized for octane enhancement.

In Europe, MTBE demand is estimated at about 60,000 b/d. MTBE use in Europe is essentially confined to octane enhancement, and about 6,000 b/d is exported to the United States. Eastern Europe (including the FSU) currently consumes about 10,000 b/d of MTBE.

In Asia, MTBE is used as both an octane enhancer and for environmental reasons. South Korea, for example, has a 1% oxygen content mandate for gasoline. Total Asian consumption is estimated at about 40,000 b/d.

Latin American consumption totals an estimated 17,000 b/d, and the Africa/Middle Eastern region consumes an estimated 10,000 b/d.

2.2 Ethanol

SUPPLY

Ethanol production around the world differs widely both by feedstock type, composition, and use. Ethanol feedstock can be either synthetic (petroleum or coal derived) or agricultural (corn, sugarcane, wine, whey, other biomass). Furthermore, ethanol is used in beverages or sold for use as an industrial solvent and as a building block for industrial organic chemicals. Finally, it is also produced for fuel, either as "hydrous" (containing about 5% water) ethanol or "anhydrous" (water-free) ethanol.

Fuel grade ethanol production is dominated by North America and Brazil. Total capacity in the U.S. is about 107,000 b/d, with another 13,000 b/d of synthetic ethanol production capacity. Canadian output capability is about 2,700 b/d. In addition to the present U.S. capacity, there is an estimated 13,000 b/d of capacity that has shut down over the past few years. Brazilian ethanol capacity is around 260,000 b/d. France is probably the next most advanced country in terms of fuel grade ethanol production, with total capacity estimated at about 8,000 b/d. Currently only a maximum of about 2,000 b/d of ethanol is used, mostly for production of ETBE in France. Other fuel grade ethanol production is limited to small pockets around the world, either for actual blending with gasoline (in New South Wales, Australia, for example about 170 b/d of ethanol is used in a 10% blend with gasoline) or for demonstration purposes.

Scanning the rest of the globe, ethanol production is devoted either to the beverage industry or the petrochemical industry. Most of the ethanol production for beverage and industrial use is located in China, India, Europe and Russia. Synthetic ethanol fills out the world balance, with about 32,000 b/d of capacity in the U.S., Europe, South Africa and Saudi Arabia.

In terms of bio-ethanol projects coming on-line in the near future, approximately 5,200 b/d of capacity is currently being built or remains in the engineering stage. Most of this future capacity will be located in the U.S. and Canada. In addition to capacity being built or engineered, approximately 17,000 b/d of capacity (again, mostly in the U.S. and Canada) can be identified that is only in the proposal or planning stage (see Appendix M, Table M-2 for a complete listing).

Expansion of ethanol production can be accomplished in several ways. Reconfiguration and debottlenecking of existing plants can increase ethanol output. Redirecting starch from the manufacture of other finished products to ethanol production can also increase ethanol output. For example, more ethanol could be manufactured at the expense of corn sweetener volume. Finally, plants could produce less industrial grade and potable alcohol and more fuel grade ethanol. These conversions could be accomplished relatively quickly, within about 90 days. It is estimated that the wet milling ethanol plants in the U.S. could provide an additional 200 million gallons per year (13,000 b/d) of extra capacity if these conversions were made, at a cost of $.80 per annual gallon. However, there are limits on how much capacity can be converted to fuel ethanol due to existing term contracts for other corn products, which producers must honor.

Dry milling ethanol plants are less flexible in producing extra output. Most run at capacity currently, and could only add new throughput by adding new capital stock, such as a new boiler. This would cost about $2.00 to $2.50 per annual gallon and could be accomplished within a year.

Adding significant quantities of new wet milling capacity would also take close to a year. The cost for building new ethanol capacity is estimated at $2.00 per annual gallon for wet mill plants to $2.50 per annual gallon for dry mill plants (e.g., a 10 million gallon per year greenfield plant would cost $20 million to $25 million dollars in capital.)

DEMAND

Fuel ethanol demand is dominated by the U.S. and Brazil. We estimate that the U.S. consumes on a yearly average about 80,000 b/d of fuel ethanol. Of this, about 40,000 b/d is used to comply with the oxygen requirement for making Federal reformulated gasoline (RFG) and oxygenated gasoline for Federal carbon monoxide wintertime programs. The rest of ethanol supply, about 40,000 b/d, is used voluntarily as a gasoline extender, usually in a 10% mix of ethanol and 90% gasoline, commonly called gasohol.

In Brazil, fuel ethanol demand is about 220,000 b/d. This figure represents two different types of ethanol consumption: that of dedicated ethanol vehicles, and that of vehicles that run on traditional gasoline. Of Brazil’s total automobile fleet, approximately 4 million cars are designed to run on 100% hydrous ethanol. Furthermore, Brazil requires that all gasoline supplied in the country contain a mixture of 24% anhydrous ethanol. This means that of Brazil’s total ethanol production capacity, about 85% cannot be exported outside of the country, either because of law (the 24% mandate) or because of dedicated use (vehicles that run on hydrous ethanol).

Fuel ethanol use elsewhere around the world is extremely limited. Ethanol production around the world is devoted to industrial uses, such as solvents, and for the beverage industry. An estimated 113,000 b/d is used for industrial uses, and an estimated 73,000 b/d is used for making alcoholic beverages.

2.3 ETBE

SUPPLY

ETBE production around the world stands at about 91,000 b/d, and this includes MTBE plants with dual capacity to produce ETBE. Most of the capacity is located in the U.S. (53,000 b/d). About 21,000 b/d of new capacity is currently being built, but the majority of this a result of a 19,000 b/d combined ETBE/MTBE plant being constructed in Canada.

ETBE capacity could be increased significantly by switching MTBE production to ETBE production. The costs and time periods needed to convert from MTBE production to ETBE production depend on the configuration of the existing ether plant; specifically, whether it uses fixed-bed or catalytic distillation process technology. With catalytic distillation process technology, the capital cost to convert from MTBE production to ETBE production would be on the order of $1 to $2 million, and about one year would be required for the alterations to be made. Fixed-bed ether units, on the other hand, would only need new instrumentation, and this would cost significantly less, probably about $200,000 per plant. This switchover could be accomplished within 6 months. It is unlikely that MTBE units outside the U.S. would make a similar conversion to ETBE production, either because they would have little access to ethanol feedstocks or would be unable to capture the subsidy that makes ethanol an affordable feedstock, or both.

As with the case of MTBE plants, existing refinery-based (FCC) ETBE units cannot be expanded, as isobutylene is a byproduct of the refinery process and the source of this byproduct cannot be expanded. As mentioned previously, there are many refineries without MTBE or ETBE units that have FCC units large enough to support commercial volumes of ether production. These ETBE units could be built at a cost of $6,000 to $10,000 per daily barrel. Moreover, butane-based world scale ether plants can be expanded, at a cost of $10,000 per daily barrel.

DEMAND

ETBE is used in limited quantities both in the U.S. and in France.

2.4 TAME

SUPPLY

TAME production is fairly limited around the world, with total capacity of only about 46,000 b/d. North America leads production, with capacity of about 22,000 b/d. Latin America has capacity for about 9,400 b/d while Europe has capacity of about 7,100 b/d. In addition, there is 16,000 b/d of TAME capacity either being planned or constructed, and there may be several others which could bring global capacity as high as 90,000 b/d.

TAME capacity can only be built economically within the refinery gate, due to the limited nature of isoamylene feedstock supply outside of the refinery process. Building TAME capacity at a refinery (Fluid Cat Cracker-based) costs in the range of $6,000-$12,000 per daily barrel (a somewhat higher range than building FCC-based MTBE units), and would take 1.5 years to construct. Expansion of existing TAME units is not possible because isoamylene is a byproduct of the refining process and the byproduct source cannot be expanded. However, additional TAME production could be built at refineries with large FCC units, but that do not now have TAME plants. However, there are many refineries without MTBE plants that have large enough FCC units to support commercial volumes of MTBE production. There is approximately 2.2 million b/d of FCC capacity in the U.S. without associated MTBE production. Using the benchmark of 1000 b/d of MTBE production for every 25,000 b/d of FCC capacity, an estimated 87,000 b/d of additional MTBE production could be built at U.S. refineries.

TAME plants cannot be economically converted from MTBE plants. The dynamics of the reaction are very different, and the process configuration would need to be changed. It would be more economic to build new TAME units in refineries without any ether units.

DEMAND

U.S.-based TAME units have generally run at low utilization rates (less than 50%). TAME is generally used for complying oxygen requirements in RFG areas.

2.5 TBA

SUPPLY

TBA production capacity is limited to about 60,000 b/d worldwide. 35,000 b/d of this is located in the Gulf Coast, 26,000 b/d is located in Europe, and 3,500 b/d is located in Russia. No new TBA projects are planned in the U.S. or around the world.

TBA capacity would be increased by switching MTBE production to TBA production. The capital expenditures required would be adding an extra tower at the ether unit and tankage for co-solvent. Total additional capital required for the conversion would be on the order of $4-5 million, and the process would take about 1.5 years.

TBA is a by-product of propylene oxide manufacturing. Existing TBA units cannot be expanded due to the limited volumes of propylene oxide that are produced. Building a new refinery-based TBA unit would cost in the range of $9,000 to $12,000 per daily barrel.

DEMAND

TBA demand is currently limited to MTBE production, or other higher value chemical end uses.

Section 3.

SUPPLY COST ESTIMATES FOR REFERENCE CASE SCENARIOS

The Reference Case for this report is defined as “business as usual” in the California refining sector; that is, MTBE continues to be used in California under current regulations. There is also a second Reference Case, which is “business as usual” with the stipulation that HR630 is passed, ending the federal mandate for oxygenate use in gasoline supplied to the federal non-attainment regions in California. California refiners will therefore have the flexibility of using zero oxygenate to produce CARB RFG during the summer gasoline season. For the purposes of this report, however, the existence of this second reference case will not affect the slope of the MTBE supply curve. There is only one reference curve; under the HR630 reference case, the refinery model, which uses the supply curves presented in this report as an input, will simply read a lower demand volume with its subsequent price level.

The price/volume relationships analyzed below are found in various tables in Appendix M.

3.1

Intermediate Term MTBE Cost Estimates

California’s supply of MTBE comes from several sources. Of the roughly 100,000 b/d of MTBE consumed in California, only a maximum of 13,000 b/d is produced in-state by California refiners with MTBE production capacity. The rest is imported: roughly 47,000 b/d from producers in Canada, the Middle East, Venezuela, and Asia, and 40,000 b/d from U.S. Gulf Coast suppliers.

California MTBE capacity
12,700 b/d

Foreign imports

Canada	15,600
Saudi Arabia	23,700
Venezuela	4,600
South Korea	1,500
Singapore	1,100
Netherlands	700
Total:	47,100

(Source: Dept. of Energy, 1998 year-to-date data)

Gulf Coast imports
40,200 (ESAI estimate)

MTBE is produced much more cheaply by Canadian and Saudi producers because of the surplus of LPGs in those regions. Butane prices in Canada, for example, have generally been roughly half that of U.S. spot prices. Middle East prices are similarly inexpensive relative to other regions.

Therefore, in determining the relationship between cost and volume for MTBE delivery to California, Canadian and Middle East MTBE volumes are the first and least expensive incremental deliveries.

The butane dehydro process starts with 1.0 gallon of normal butane, which is isomerized to isobutane and then dehydrogenated into isobutylene. This is then reacted with 0.344 gallons of methanol at a total variable operating cost of about 7 cents/gallon. Assuming a methanol price of 61.2 cents/gallon, a butane cost of 14.3 cents/gallon [1], and a 10 year capital life using a 15 percent discount factor for a 15,000 b/d plant, the selling price of Canadian/Middle East MTBE is calculated at 73.3 cents/gallon. Canadian MTBE (15,600 b/d) is delivered to California the cheapest, at 76 cents/gallon, due to low transportation costs, and Saudi MTBE (23,700 b/d) is delivered to California at 83 cents/gallon, due to incrementally more expensive transportation costs. The selling price of MTBE derived from U.S. Gulf Coast dehydro merchant plants (40,200 b/d) is higher, at 88 cents/gallon, due to more expensive butane costs (assumed to be 28.6 cents/gallon for this study).

A gallon of MTBE made from FCC-derived isobutylene is manufactured by reacting 0.8 gallons of isobutylene with 0.344 gallons of methanol at a varable operating cost of 3.4 cents/gallon. Using the methanol price of 61.2 cents/gallon, a butane cost of 28.6 cents/gallon, and a 10 year capital life using a 15 percent discount factor for a 3,000 b/d plant, the selling price of FCC-derived MTBE is 86.5 cents/gallon. The cost of butylene as alkylation feedstock was calculated as 70 cents/gallon, based on alkylate value and butane prices located in Appendix K.

In summary, the intermediate term supply curve for MTBE is built by determining the origin of California's supply and calculating the differential production costs for those volumes.

There is enough *global* capacity to meet any new sudden MTBE demand surge with imports. In other words, MTBE could be supplied by offshore producers before any new large scale plants would need to be built in the U.S. Out of a global capacity of about 520,000 b/d, about 390,000 b/d is currently produced (a utilization rate of 75%). With 130,000 b/d of spare capacity, the world market could absorb an increase in U.S. demand above its current 250,000 b/d consumption rate. Most of this would be supplied by Europe and the Middle East, regions of the world where most excess capacity exists.

3.2

Long Term MTBE Cost Estimates

[1] The Canadian/Middle East price is estimated to be half of the 28.6 cents/gallon benchmark price for US butane used in this study

In the long term, the supply curve will be flatter, as more low-cost MTBE production capacity comes on line. In Appendix A, Table A-1, several new MTBE plants are identified which are either being constructed or are in the planning stages. This includes 19,000 b/d of Canadian capacity, as well as close to 50,000 b/d of Middle Eastern capacity. All of this capacity is low-cost, as it will be located in LPG-surplus regions.

To build the long term supply curve for MTBE delivery to California, the same cost formulas from Section 3.1 are used. However, using projected future MTBE capacity from Table A-2, more low-cost MTBE is available in the long term. For example, roughly 31,000 b/d of Canadian MTBE is delivered to California at 76 cents/gallon, while 60,000 b/d of Middle Eastern MTBE (Saudi Arabia, Iran, Qatar) is delivered to California at 83 cents/gallon. It is assumed that 75 percent of the new capacity in the Middle East and Canada is available for delivery to North America.

The rest of the supply curve is filled out with production from California (allowing for an additional 2,000 b/d of new capacity to come online) as well as Latin American production. U.S. Gulf Coast production is not included as it is higher-cost than California's alternatives. In the long run, US Gulf Coast MTBE is likely to continue to be imported to California; however, the quantity of low-cost MTBE coming on-line from LPG-surplus areas suggests that Gulf Coast producers will have to accept a lower price due to the cost pressure from producers in Canada and the Middle East.

Section 4.

SCENARIO: *MTBE BANNED IN CALIFORNIA ONLY*

SUPPLY COST ESTIMATES FOR ALTERNATIVE OXYGENATES

The first scenario in this study assumes that MTBE is banned in the state of California. Different policy assumptions are examined with respect to their effect on the cost of alternative oxygenates within the marketplace. With the exception of the policy assumption of HR 630 passing (which would end the federal oxygen mandate in CARB RFG and thereby allow California refiners the option of using no oxygenate at all during the summer season), other oxygenates are needed by California refiners to comply with federally and state mandated minimum oxygen levels in CARB RFG.

The effect of a California ban on MTBE on the cost of ethanol, ETBE, TAME, and TBA is analyzed in Sections 4.1 through 4.4. While this study examines six different policy assumptions (or combination of policy assumptions), the only policy assumption that will have an impact on any of the supply curves will be those involving removal of tax credits for ethanol and ETBE. This is because while HR 630 may reduce the ultimate volume of oxygenate (whether MTBE, ethanol, ETBE, etc), it will not change the slope of the supply curve. Likewise, granting ethanol a 1 psi RVP waiver may result in a higher amount of ethanol consumed in California, but it will not change the slope of the supply curve. Since tax credit issues change the ultimate price of ethanol and ETBE, this is the only policy assumption that will result in a different supply curve for these oxygenates.

4.1

Ethanol Use in California (MTBE Ban in California Only)

Four supply curves need to be considered for the alternative oxygenate ethanol. The first set of supply curves considered will represent the price of ethanol with current tax regulations in place (i.e., gasoline blenders are eligible for up to a $.54/gallon tax credit for ethanol in blends of up to 10%, and a pro-rated tax credit for blends of less than 10%, such as 7.7% and 5.7%), both for the intermediate term and the long term. The second set of supply curves will represent the price of ethanol without the tax credit, both for the intermediate term and the long term.

4.1.1

California' ethanol requirements

If MTBE were banned in California, and ethanol was chosen to replace it as the oxygenate used for blending with CARB RFG, less ethanol than MTBE would be needed under current regulations *for oxygen purposes only (not volume)* in CARB RFG because ethanol contains almost twice the amount of oxygen by weight than does MTBE.

Ethanol contains almost 35% oxygen, and therefore only about 5.7% ethanol is needed in a gallon of gasoline to achieve the 2% oxygen target. This study assumes that California consumes on average about 965,000 b/d of gasoline in the intermediate term. The amount of ethanol needed under the current regulations *for oxygen purposes only (not volume)* is therefore about 55,000 b/d to achieve a 2.0 wt. % oxygen level, and 97,000 b/d to achieve a 3.5 wt. % oxygen level. In the long term, California is assumed to demand 1.022 million b/d of gasoline. The amount of ethanol needed at this demand level is about 58,000 b/d to achieve a 2.0 wt. % oxygen level, and 102,000 b/d to achieve a 3.5 wt. % oxygen level.

4.1.2

Ethanol availability in the U.S.

Currently, the U.S. produces about 80,000 b/d of fuel ethanol on an average annual basis, and imports relatively small volumes occasionally from Central America. On-line capacity in the U.S. and Canada equals 110,000 b/d. Therefore, the U.S. fuel ethanol industry produces at roughly 70% of capacity on an annual basis, and there is about 30,000 b/d of spare capacity that could be used to supply California. This spare capacity is generally concentrated among the major producers of ethanol. While there are several ethanol plants that have shut down over the years, and might be counted as capacity that could come online to meet Californian demand, we can assume that these plants are not *currently* operating because they are not competitive. If they were competitive they would be producing at the current price for ethanol ($1.20/gallon). Also, these small producers do not have the economies of scale that larger producers like ADM currently enjoy. ADM and the larger producers would therefore increase production or increase capacity before some of the smaller producers came back to production.

4.1.3

Ethanol Supply curve Estimates (Tax Credits Available)

The price/volume relationships analyzed below are found in various tables in Appendix M, Table M-3 and M-4. It is assumed that all subsidies including tax credits for blenders are in place throughout the country.

4.1.3.1

Intermediate Term Cost Estimates

Ethanol is blended in gasoline (primarily in the Midwest or Padd II region) where it is more economical to use than MTBE or can be blended with regular or subgrade unleaded gasoline to make a midgrade or premium gasoline.

In the intermediate term (i.e., before substantial new ethanol capacity could be built and substantial quantities of ethanol supplied to the market), California CARB RFG blenders would have to outbid these other users of ethanol in order to secure ethanol supply and comply with California and Federal oxygen regulations. In other words, the price of ethanol will have to increase to the point where it is cheaper for ethanol blenders outside of California to switch to MTBE for their oxygenate use, or cheaper to buy 100 percent petroleum-based gasoline instead of using ethanol in a mix with regular unleaded gasoline (gasohol).

In order to make these comparisons, ethanol needs to be valued correctly. Ethanol's value to gasoline blenders will first depend on whether it is being used as an oxygenate in oxygenated gasoline, or whether it is being used in gasohol as a gasoline extender.

If used as an oxygenate, ethanol's value will depend on the cost of MTBE, the cost of octane and Reid Vapor Pressure (RVP). Using a 2.7 wt. % oxygen level in oxygenated gasoline, ethanol's value can be expressed using the following equation [2]:

$$P_{EOH} = (0.852\ P_{B\text{-}MTBE} - 0.923\ P_{B\text{-}EOH} + 0.148\ P_{MTBE} - C_{EOH})/0.077$$

Where

P_{EOH} = Price of ethanol
$P_{B\text{-}MTBE}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with MTBE.
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with ethanol
P_{MTBE} = Price of MTBE
C_{EOH} = Any costs associated with blending ethanol

If used as a gasoline extender, ethanol's value will depend on the retail price of gasoline, the rack price of gasoline, and the cost of octane. Using the typical 10 percent blend of ethanol

[2] The derivations of this formula (EOH valued as an oxygenate) and the following formula (EOH valued as gasohol), provided by MathPro, Inc., can be found in Appendix B.

found in most gasohol, ethanol's value can be expressed using the following equation:

$$P_{EOH} = -\,(\,P_{R\text{-}MOGAS} - P_{MOGAS} - P_{R\text{-}GASOHOL} + 0.9\ P_{B\text{-}EOH} + C_{EOH}\,)\,/\,0.1$$

Where

P_{EOH} = Price of ethanol
$P_{R\text{-}MOGAS}$ = Retail (pump) price of pool gasoline
P_{MOGAS} = Rack price of pool gasoline
$P_{R\text{-}GASOHOL}$ = Retail (pump) price of gasohol
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with ethanol
C_{EOH} = Cost associated with blending ethanol

In order to determine the price/volume relationships, blocks of outside supply are identified, and breakeven ethanol values are determined to attract these volumes away from their markets.

The blocks of ethanol used for this study are on a state-by-state basis. Ethanol volumes consumed in each state were estimated using 1996 ethanol usage data from the Federal Highway Administration (percentages of 10% and less than 10% blends of ethanol used in total state gasoline usage) and applying it to 1997 gasoline sales data supplied by the Energy Information Agency *Petroleum Marketing Annual* .

Since gasoline prices (and to a certain extent, MTBE prices) differ in each state, ethanol will be valued differently according to its market. Retail and rack gasoline price data from the U.S. Energy Information Agency's *Petroleum Marketing Annual* publication were used to determine gasoline prices for all states that consume ethanol. Prices were adjusted for use in this study by basing them on a base of 62 cents/gallon pool gasoline rack price and a $1.00/gallon retail price and then adding a differential based on the relative prices found in each state. For example, Indiana's rack price for gasoline was 1.5 cents/gallon higher than that of Mississippi, which had the lowest U.S. rack price; therefore, for the purposes of this study, the rack price for Indiana is 63.5 (62 plus 1.5). See Appendix C for a ranking of state-by-state rack and retail gasoline prices.

Using the formulas expressed above, ethanol values were determined for each state. Arizona, Nevada, Washington, California, New Mexico and Colorado were assumed to use ethanol for oxygenate blending instead of as a gasohol (thus the higher value for ethanol). Several states, notably Ohio, South Dakota, Illinois and Missouri, have state incentives for ethanol use, in the form of an income tax exemption. The presence of such state subsidies increases the price at which ethanol will be bid away from these states, by 10 cents per gallon of ethanol for Ohio, 13 cents for Illinois (estimated using the 2% sales exemption on a 6.25% sales tax), and 20 cents for Missouri and South Dakota. The estimated volume of ethanol sales (b/d) and calculated ethanol values (cents/gallon) for each state are listed below:

Mississippi	126	63.1	Maryland	173	63.7
Louisiana	474	63.3	Alabama	1,302	64.0
North Carolina	72	63.6	Tennessee	1,021	64.4
Wisconsin	2,105	63.6	Texas	3,410	65.1
Pennsylvania	4,419	63.6	New York	1,492	65.2

N. Dakota	385	65.2
Nebraska	1,546	65.2
Kentucky	304	66.1
Florida	144	66.2
Indiana	5,391	66.2
Kansas	312	66.7
Iowa	4,277	67.2
Michigan	2,925	67.6
New Jersey	821	69.9
Ohio	12,883	74.1
Illinois	10,392	78.3
S. Dakota	1,175	85.9
Missouri	1,243	87.1
Arizona	1,453	90.7
Nevada	827	91.0
Montana	42	91.7
Washington	1,939	91.8
California	2,000	94.7
New Mexico	1,156	95.4
Colorado	2,248	96.1
TOTAL:	66,119	

In the supply curve constructed from the above data, the block representing ethanol consumed in Minnesota is excluded from the volume that can be bid away to California blenders. Minnesota has a year-round oxygenate mandate stipulating a 2.7% minimum oxygen content in all gasoline sold in the state. According to industry sources, the language in this regulation precludes the use of MTBE, and as such, the mandate amounts to an ethanol mandate. Thus, there is approximately 13,500 b/d of ethanol consumed in Minnesota that cannot be bid away.

There are two other blocks of supply that need to be considered. These are volumes of ethanol imported from the Caribbean and ethanol that could be supplied by increasing U.S. utilization capacity to 100 percent.

U.S. law (the Caribbean Basin Initiative) states that the equivalent volume of up to seven percent of U.S. ethanol production can be imported duty-free into the United States. Historically, this has been essentially unfinished ethanol from beer still/wine alcohol that is exported from the European Union, and sent to countries like Jamaica and El Salvador, where it is upgraded and sent to the U.S. Industry sources report that the ethanol is priced at approximately 60 cents/gallon, and that freight and insurance would bring the delivered price to California to almost 83 cents/gallon. With an assumed production of 110,000 b/d in the U.S., the Caribbean ethanol volume available is estimated at 7,700 b/d.

Since U.S. ethanol capacity is 110,000 b/d and the average annual production is 80,000 b/d, there is approximately 30,000 b/d of ethanol that can be supplied to California. Because individual ethanol plant data is not available, and each plant runs on different economics, it is not possible to determine what price for ethanol would cause each plant in the U.S. to reach 100 percent of capacity.

However, it is possible to create a notional ethanol producer's margin, and compare this to historical utilization capacity. The margin for an ethanol producer is equal to the price received for ethanol and other corn by-products (such as distiller's grains and starches) minus the cost of producing ethanol (composed mostly of corn feedstock costs). Historical price data for corn, dried distiller grains, gluten meal and gluten feed were obtained, as well as other typical variable and fixed cost information for both wet and dry milling ethanol producers (See Appendix E & F). A notional margin for both wet and dry milling producers was calculated on a monthly basis for the last six years, and compared to production data from the Energy Information Agency (see Appendix G). According to this data, it appears that the only time that utilization rates in the U.S. reached near 100% (winter 94-95), the notional margin (averaged for both wet and dry milling producers) was approximately 40 cents/gallon.

The historical average net production cost (a weighted average for both wet and dry milling producers), according to the data used in this report, has been approximately $1.03/gallon over the past six years. Therefore, the price required to bring U.S. production to full capacity is equal to the $1.03/gallon net production cost plus 40 cents/gallon margin, or $1.43/gallon. Net of the 54 cent/gallon subsidy, this equals 89 cents/gallon.

With approximately 58,000 b/d of ethanol bid away from other states, 7,700 b/d available through the Caribbean, as well as 30,000 b/d available by boosting production, a supply curve can be constructed up to demand levels of 98,000 b/d. This is the approximate demand level that would be necessary for California if ethanol were granted a 1 psi RVP waiver, effectively allowing blenders to use up to 3.5 wt. % oxygen level in CARB gasoline.

MTBE demand will fall to zero in California as a result of a ban on its use. Ordinarily this would result in a severe drop in MTBE's price, and perhaps a knock-on effect in the price of other oxygenates. However, blenders outside of California that use ethanol will need to replace oxygen or octane if ethanol is bid away; and they will most likely use MTBE. Since end-users of ethanol and MTBE will in essence be swapping demand for oxygenates, there should not be any net change in price for MTBE.

In summary, the intermediate term supply curve for ethanol delivered to California is constructed by determining the correct ethanol value in each state that consumes the fuel, and assuming that the amount consumed by each state will be bid away by Californian end-users once the price has risen to breakeven levels above which the original consumers would find it too expensive. Minnesota ethanol is not considered, and in addition there is 7,700 b/d of ethanol that is available through the Caribbean, as well as 30,000 b/d of ethanol that is available by increasing producers' utilization rates to 100%.

4.1.4.2

Long Term Ethanol Cost Estimates

Within 2-3 years, another 5,300 b/d of ethanol capacity in the U.S. and Canada that is either under construction or in planning/engineering stages would come on line and add to supply. Furthermore, the increased demand for ethanol would justify the construction of nearly 17,000 b/d of capacity in the U.S. that has already been planned or proposed (see Appendix A, Table A-2, for a listing of plants expected to come on-line). In addition to the projects already planned, new producers will enter the market, attracted by higher intermediate term prices and increased demand caused by a switch to ethanol consumption in California.

The long term scenario assumes that in addition to the approximately 80,000 b/d of ethanol already consumed in the U.S. (excluding California) another 58,000 b/d to 102,000 b/d would be produced to supply California's needs. Assuming that approximately 91% of ethanol will continue to be processed with corn feedstock, and that approximately 2.6 gallons of ethanol are produced from a bushel of corn, this increased demand will require additional feedstocks of 310 to 550 million bushels of corn.

In a long term time period, the additional required volumes of corn feedstock will be supplied in response to higher demand and higher corn prices in the intermediate term. Additional corn production is expected to respond to the long term supply elasticity of price for corn (the percentage change in corn price divided by the percentage change in supply of corn). The U.S. Department of Agriculture (USDA) has generally used the value of 0.3 as an estimate for this value. Using this elasticity value, it was possible to calculate the increasing price for corn at various volumes additional ethanol supplied to the market. For the purposes of this study, a baseline of $2.60/bushel was used. See Appendix J for calculations.

It is also expected that as a result of the additional processing of corn for ethanol production, there will be a large increase in the supply of by-products, such as distillers' dried grains (DDG), corn gluten feed, corn gluten meal and corn germ. It expected that the price of these by-products will decline in response to the long term supply elasticities for these products. Previous USDA studies have reported that an increase in ethanol production of 4.8 billion gallons would decrease corn gluten meal prices by 7 percent, corn gluten feed prices by 12.3 percent, and distillers' dried grains by 4 percent. [3]

Using this data, long term supply elasticities were calculated for each by-product of ethanol production. These elasticities were then used to determine the price of DDG, corn gluten feed, corn gluten meal, and corn germ at various volumes of ethanol supplied to the market in the long term. See Appendix J for calculations.

By determining the long term price of corn and the long term price of ethanol by-products, it was possible to calculate long term net production costs at various volumes of ethanol. All other fixed and variable costs besides corn cost and by-product prices were held constant.

In the long term scenario, ethanol prices are expected to decline to their marginal cost of production as calculated above. Since most production will still be located in the large corn-producing states, the transportation cost of 15 cents/gallon remains.

4.1.4

Loss of Ethanol Tax Credit

The following section estimates intermediate and long term cost of ethanol delivered to California in the absence of the 54 cent/gallon Federal subsidy for ethanol.

The approach used for determining the supply curve for ethanol delivered to California in the absence of a Federal subsidy is to estimate the pattern of supply and use of ethanol, given the loss of the ethanol tax and with no California ban of MTBE, i.e., the current regulatory situation, but with no ethanol tax break. As is explained below, this study assumes that little or no ethanol use will continue. The supply curve for delivery of ethanol to California is then

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[3] House, R., M. Peters, H. Baumes, and W.T. Disney "Ethanol and Agriculture: Effect of Increased Production on Crop and Livestock Sectors," USDA, Economic Research Service. Agricultural Economic Report Number 667. May, 1993.

constructed by estimating the price necessary to induce ethanol plants to resume operation.

4.1.4.1

Intermediate Term Cost Estimates
Ethanol Without Tax Credits

The General Accounting Office has reported that if the tax credit for ETBE and ethanol was revoked, then production in the U.S. of these fuels would decline by at least 50% and perhaps to zero. As the tax credit is eliminated, the effective price of ethanol rises for end-users, discouraging demand, encouraging gasoline blenders to use cheaper substitutes like MTBE for oxygenate needs and use of 100% gasoline instead of a 10% ethanol blend. As demand drops off, the price of ethanol will decline, causing ethanol producers to make less ethanol. As the cost of producing ethanol is high relative to gasoline and MTBE, if the ethanol selling price falls too far, many producers will go out of business. In other words, the tax credit available for ethanol keeps the price of ethanol artificially high. Without the subsidy, ethanol prices would have to decline substantially to be either competitive with MTBE or gasoline.

Since the prices used in this report for gasoline and MTBE are lower than the calculated production cost for ethanol, it is assumed in this study that ethanol production would fall to zero in the U.S. In order for producers to supply ethanol, the price will have to rise to at least the cost of production.

Data on production costs are not available for individual ethanol producers in the U.S. Instead, a notional net production cost formula can be used, based on the cost of corn and the credits received for ethanol by-products such as DDGs, corn germ, corn gluten meal and corn gluten feed as in Section 4.1.4.2. According to interviews with industry members familiar with the ethanol industry, the most important cost segment for the typical ethanol producer is the cost of corn. Corn prices can vary substantially from state to state. In Appendix H, historical corn prices for the last 6 years are listed for each state. Not surprisingly, the lowest corn prices in the country are found in those states with the largest amount of corn output.

To determine the price of ethanol needed to induce production in the absence of the subsidy, the net cost of ethanol production was calculated for wet milling producers and dry milling producers in each state that produces ethanol, based on the cost of corn in each state, since this is the most germane segment of production costs. By-product credit prices and all other expenses were assumed to remain constant for all states (see Appendix I).

It appears that low-cost ethanol from the Caribbean, entering the U.S. duty-free, would be the first volume of ethanol available for use by California. Minnesota's ethanol requirements (13,500 b/d) are first supplied by the low cost wet milling producers in Minnesota and Iowa, and California's ethanol requirements are then supplied with the remainder of ethanol production in the U.S., based on order of production costs. In general, California is first supplied by the lower-cost wet milling operations, and then, as the price of ethanol rises to cover the costs of production of dry milling operations, ethanol is supplied by these producers.

In summary, then, the intermediate term supply curve for ethanol delivery to California is constructed by determining the ethanol volumes that come on line as the price of ethanol rises to meet the cost of ethanol production in each state (which, in turn, is determined by the cost of corn in each state).

The estimates of state corn prices and production volumes, as well as estimated costs of production for wet milling and dry milling operations in each state, are detailed in Appendix H and I. Wet milling and dry milling ethanol producers are identified, where possible in Appendix A, Table A-2.

4.1.4.2

Long Term Cost Estimates
Ethanol Without Tax Credits

The prices at which ethanol will be delivered to California in the long term in the absence of the Federal subsidy are calculated similarly to the intermediate term case without the Federal subsidy. That is, the net production cost for ethanol was determined by state, using differential corn costs.

As stated above, according to the USDA data used in this study, those states with the largest volumes of corn production tend to be the states with the lowest corn costs. In the long term scenario, which allows for new grassroots ethanol plant construction, ethanol production will migrate to those states that have the lowest corn costs (and thus the lowest net ethanol production costs). In addition, ethanol production will be limited to wet-milling operations, which enjoy lower net production costs than dry milling operations due to the higher value of the by-products associated with wet milling. In other words, without the benefit of the Federal subsidy, which allows ethanol prices to remain higher than they would without the subsidy, producers will have to seek low-cost regions and production configurations (wet milling) in order to remain viable producers.

Thus, in the long run scenario, dry milling operations in the United States cease (these plants represent approximately 34,000 b/d of ethanol production today), due to their much higher net production costs. Wet milling survives in those states where facilities presently exist (Minnesota with 2,600 b/d of capacity, Nebraska with 10,100 b/d of capacity, Illinois with 33,300 b/d of capacity, Iowa with 25,400 b/d of capacity, and Indiana with 5,500 b/d of capacity). In order to replace the balance of ethanol lost by the shut-in of dry milling plants (33,700 b/d), new wet milling plants will probably be built in those states that offer state production incentives (generally this is in the form of a 20 cent/gallon subsidy up to a pre-determined volume of ethanol per year). The states that offer this subsidy are Kansas, Minnesota, South Dakota, and Nebraska. The 33,700 b/d of new wet milling production that replaces shut-in dry milling plants in the long run is assumed to be split evenly between these states.

The following are the long term net production costs and volumes of ethanol available from those states that will supply the fuel. In essence, these cost and volume relationships constitute the long run supply curve for ethanol delivered to California in the absence of the Federal ethanol subsidy:

State	**Ethanol net**	**Existing wet**	**Long term**	**Long term**

	production cost	milling capacity	additions of wet milling capacity	capacity total
South Dakota	$0.79	0	8,423	8,423
Minnesota	$0.82	2,609	8,423	11,032
Iowa	$0.85	25,440	0	25,440
Nebraska	$0.88	10,111	8,423	18,534
Indiana	$0.89	5,545	0	5,545
Illinois	$0.90	33,268	0	33,268
Kansas	$0.90	0	8,423	8,423
TOTALS:		76,973	33,691	110,664

4.2

ETBE Use In California (MTBE Ban In California Only)

The supply curves described in this section utilize analysis from the previous section regarding the cost estimates for ethanol. This is necessary since one of the main feedstocks for ETBE manufacture is ethanol. Therefore, cost estimates for ethanol (both with and without the tax credit) must be used to determine the cost of different quantities of ETBE.

4.2.1

California's ETBE Requirements

ETBE contains about 15.7% oxygen, and therefore about 12.7% ETBE is needed in a gallon of gasoline to achieve the 2.0 wt. % oxygen target. This study assumes that California consumes on average about 965,000 b/d of gasoline in the intermediate term. The amount of ETBE needed under the current regulations *for oxygen purposes only (not volume)* is therefore about 123,000 b/d to achieve a 2.0 wt. % oxygen level, and 165,000 b/d to achieve a 2.7 wt. % oxygen level. In the long term, California is assumed to demand 1.022 million b/d of gasoline. The amount of ETBE needed at this demand level is about 130,000 b/d to achieve a 2.0 wt. % oxygen level, and 175,000 b/d to achieve a 2.7 wt. % oxygen level.

4.2.2.

ETBE Availability

As stated in Section 2.2, the U.S. currently produces only a small quantity of ETBE, but capacity is estimated at about 53,000 b/d and could increase substantially if existing MTBE plants were converted to ETBE output. In addition, there is approximately 40,000 b/d of ETBE or MTBE/ETBE capacity outside North America. As explained below, however, it is unlikely that this foreign source of potential ETBE would be supplied to the California market.

4.2.3

ETBE Cost Estimates (Tax Credits Available)

The price/volume relationships analyzed below are found various tables and charts in Appendix M, Table M-7 and M-8. The prices and blending values of various petroleum products used in the analysis below are found in Appendix K. It is assumed that all subsidies including tax credits for blenders are in place throughout the country.

4.2.3.1.

ETBE Intermediate Term Cost Estimates

The cost of ETBE is highly dependent on the price of ethanol, since ETBE contains about 43% ethanol. ETBE producers supplying California, therefore, would require about 53,000 b/d of ethanol to manufacture 123,000 b/d of ETBE (123,000 times 0.43), and 71,000 b/d of ethanol to manufacture 165,000 b/d of ETBE. Increased demand for ETBE will necessarily increase demand for ethanol.

ETBE is produced by reacting .695 gallons of isobutylene with 0.43 gallons of ethanol, at a variable operating cost of 4.6 cents. Production costs therefore depend heavily on the price of ethanol, and alkylation economics (see Appendix D and Appendix K for blending values and production cost formulas).

The current tax codes allow the ETBE tax credit to be claimed by the blender and seller of gasoline containing ETBE. Therefore, the refiner using ETBE will claim the credit. Merchant producers of ETBE in the past have added a 23.2 cent/gallon surcharge on the market price of ETBE, which was then claimed by the purchaser of the ETBE as a tax credit.

It should be noted that although there is close to 40,000 b/d of existing ETBE or combined MTBE/ETBE production outside of North America (located in Brazil, Europe, and Saudi Arabia), imports of ETBE from foreign producers would not be eligible for the U.S. federal ethanol tax credit, which applies to domestically produced ethanol only. Therefore, it would be more economic for existing ether capacity in the U.S. to convert to ETBE production, so that purchasers of ETBE (refiners) could capture the subsidy.

The ETBE supply curve shown in Appendix D is built up in 5,000 b/d increments, each of which will require about 2,150 b/d of ethanol (5,000 b/d times 0.43 = 2,150 b/d). This ethanol would be bid away from other users around the country in the same fashion as was described in the intermediate term ethanol supply curve above.

It is assumed that the intermediate term allows for both the relatively quick and inexpensive conversion of fixed-bed MTBE plants to ETBE production, as well as the more expensive and time consuming conversion of MTBE plants employing catalytic distillation process technology.

The input price of ethanol for ETBE production at these facilities is derived from the price/volume relationships developed for the intermediate term ethanol supply curve described in Section 4.1.3.1. The input price in this case, however, is the market price for ethanol, or the breakeven price of ethanol plus 54 cents (the delivered price to California, which is 15 cents/gallon higher, is not used).

The refinery model used in this study assumes that in the California-only ban of MTBE scenario, the 13,000 b/d of existing in-situ ether plants in California will continue to manufacture MTBE and TAME for gasoline exported to Arizona/Nevada, and will not convert to ETBE production.

The first volumes on the supply curve, therefore, are approximately 18,000 b/d of ETBE supplied from the Western Canadian ether plant that is converted to ETBE production. This will require about 7,700 b/d of ethanol, which is delivered to Canada with a transportation cost of 15 cents/gallon. Finished ETBE is delivered to California with a transportation cost of 3 cents/gallon.

The rest of ETBE delivered to California comes from the Gulf Coast, where most U.S. ether production is located. Presumably, enough capacity in the Gulf would be converted from MTBE production to ETBE production. Again, the ethanol input price for ETBE produced in the Gulf Coast is read from the intermediate term ethanol supply curve from Section 4.1.3.1, with an 8 cent/gallon transportation cost from the Midwest to Gulf Coast. Finally a 9 cent/gallon transportation cost is assessed for delivery of ETBE from the Gulf Coast to California (this transportation cost includes a 1 cent/gallon surcharge for water soluble products).

The supply curve for ETBE is built up in this fashion as volumes arrive from the Gulf. As MTBE production is switched to ETBE production, ether capacity is tied up in the U.S., reducing MTBE supply in the U.S. However, because reduction MTBE supply is matched barrel by barrel with a reduction in MTBE demand (MTBE is banned in California), there is no net reduction in the U.S. MTBE supply/demand balance until MTBE capacity is switched to ETBE capacity above and beyond the reduction in U.S. MTBE demand. At this point, blenders of oxygenated gasoline or RFG gasoline outside California will begin facing a shortage of MTBE, and look to alternative oxygenates to satisfy their oxygen requirements.

The reduction in MTBE demand caused by its ban in California is estimated at approximately 105,000 b/d. Therefore, tying up ether production in excess of 105,000 b/d will result in a net reduction of U.S. MTBE supply, and blenders will begin valuing ethanol, the next most available alternate oxygenate, for its oxygenate value. Therefore, the input value of ethanol for ETBE production will rise.

To determine this input price of ethanol as ethanol is valued as an oxygenate, it is useful to determine where ethanol would potentially be demanded in the U.S. Wintertime oxygenated gasoline will be required in several states, notably New Mexico, Arizona, Washington, Oregon, Utah, Nevada, Montana and Colorado. Using data from the U.S. Energy Information Agency's 1997 *Petroleum Marketing Annual*, potential ethanol demand at 2.7 wt.% oxygen level was estimated, as well as potential ethanol demand at 2.0 wt. % oxygen level (RFG areas). EIA gasoline demand was multiplied by 0.077 or 0.057 depending on the oxygen content of the region:

State	**Actual oxygenated/RFG gasoline demand**	**Equivalent ethanol demand**	**Ethanol breakeven value**
New Mexico	7,688	592	88.8
Utah	2,388	184	83.1
Nevada	16,338	1,258	84.5
Montana	590	45	84.6
Oregon	22,114	1,703	87.6
Arizona	23,933	1,843	88.7
Washington	36,350	2,799	88.9
Colorado	33,455	2,576	90.4
Texas (RFG)	282,040	16,076	94.5
Texas (oxy)	8,243	635	94.9
New Hampshire (RFG)	22,443	1,279	97.6
Connecticut (RFG)	88,933	5,069	97.7
Rhode Island (RFG)	35,693	2,034	97.9

The ethanol that would be potentially demanded by these states will also be valued differently in each state, depending on relative gasoline prices and MTBE prices. Using the equation presented in Section 4.1.3.1, set up for valuing ethanol as an oxygenate at a 2.7 wt. % oxygen level in states where oxygenated wintertime gasoline is required, and 2.0 wt. % in states were RFG gasoline is required, ethanol values were calculated for the volume potentially demanded by each state. The same methodology as in Section 4.1.3.1 was used to determine state by state gasoline rack prices, (see Appendix C for this data). The above table ranks several states in order of the value they assign to ethanol, and the potential volumes of ethanol they would demand.

On the point on the ETBE supply curve where MTBE capacity is crowded out (105,000 b/d), the curve begins reading the above breakeven levels of ethanol plus 54 cents/gallon, plus 8 cents transportation to the Gulf Coast. For example, as the ETBE supply curve reaches 120,000 b/d, 15,000 b/d of MTBE demand is crowded out. This increment of 15,000 b/d of ETBE demand will require 6,500 b/d of ethanol. On the table above, 6,500 b/d of cumulated ethanol demand equates to an ethanol value of 88.9 cents/gallon.

In sum, then, the volumes of ethanol required as feedstock for ETBE production in the U.S. once ETBE production surpasses 105,000 b/d on the supply curve are valued at their oxygenate value. The price/volume relationship is determined by potential volumes of ethanol demand from states that will require oxygenates for wintertime oxygenated gasoline.

4.2.3.2

ETBE Long Term Cost Estimates

In the long term scenario, ETBE production facilities are either converted from MTBE capacity or grassroots ETBE facilities are built.

As in the intermediate term case, the long term supply curve for ETBE delivered to California is highly dependent on the price of ethanol, since ETBE contains about 43% ethanol. The difference in this case is that the input cost of ethanol is determined by the long term supply curve for ethanol. All other costs are the same as in the intermediate term case.

The refinery model used in this study assumes that in the California-only ban of MTBE scenario, the 13,000 b/d of existing in-situ ether plants in California will continue to manufacture MTBE and TAME for gasoline exported to Arizona/Nevada, and will not convert to ETBE production.

The first block of ETBE supplied to California is assumed to be based in Canada. This includes the 19,000 b/d of new capacity coming on line (see Appendix A, Table A-1), for a total of 37,000 b/d of ether capacity in Canada. The transportation cost for ethanol delivered to Canada is assessed at 15 cents/gallon, and the transportation cost for finished ETBE delivered to California is 3 cents/gallon.

The remainder of ETBE delivered to California is supplied from ether capacity in the Gulf Coast. Ethanol input costs to the Gulf Coast are also read off the long term supply curve for ethanol, and an 8 cent/gallon transportation cost is added to the delivered cost of ethanol in the Gulf Coast. A 9 cent/gallon transportation cost is added to the delivered cost of ETBE from the Gulf Coast to California (including the surcharge for water soluble materials).

In the long term, it is assumed that MTBE capacity is not crowded out as it was in the intermediate term, because the long term allows for additional MTBE plants to be built.

4.2.4

ETBE: Loss of Tax Credit

The most significant element of the supply curves for ETBE without the ethanol tax credit is that the delivered price to California will contain the 23.2 cent/gallon pro-rated price of ethanol instead of netting it out.

4.2.4.1

ETBE Intermediate Cost Estimates Without Tax Credit

Determining the supply curve for ETBE without the ethanol subsidy requires reading off the already-established intermediate term price curve for unsubsidized ethanol (see Appendix M, Table M-5).

Again, it is assumed that the intermediate term allows for switching both types of MTBE process technology to ETBE production, except in California, where it is assumed that ether units will manufacture MTBE and TAME for gasoline exported to Arizona and Nevada.

The first 18,000 b/d of ETBE supplied to California are produced from Canadian MTBE capacity converted to ETBE production. The input cost for ethanol reads the intermediate supply curve for ethanol without tax credits (see Section 4.1.4.1). This Canadian ETBE capacity will require approximately 7,700 b/d of ethanol, which be supplied from volumes of ethanol imported from the Caribbean, as this ethanol can be imported at lowest cost (83 cents/gallon) and is therefore economic even without the tax credit.

The remainder of California's ETBE requirements are supplied from ether capacity in the Gulf Coast. The ethanol input cost is read from the curve described in Section 4.1.4.1, with a transportation cost of 8 cents/gallon. A transportation cost of 9 cents/gallon is added to the delivered cost of ETBE to California from the Gulf Coast (this includes the 1 cent/gallon surcharge for water soluble materials.

As explained in Section 4.2.3.1, after 105,000 b/d of MTBE capacity is converted to ETBE production, ether production capacity in the U.S. that would normally supply blenders outside of California with MTBE is tied up. This reduces net oxygenate supplies in the U.S., and results in a higher supply curve for ethanol, as ethanol is now valued for its oxygenate value.

However, the elimination of the ethanol subsidy causes production of ethanol only at prices which are above the oxygenate values of ethanol determined in Section 4.2.3.1. In other words, the lowest price at which ethanol can be economically produced, 98 cents/gallon, is greater than the breakeven oxygenate values which ethanol would be bid to, as former blenders of MTBE turned to ethanol, as determined in Section 4.2.3.1 (97.9 cents/gallon, ex subsidy). Therefore, the ETBE curve described in this section continues to read its input cost of ethanol from the curve described in Section 4.1.4.1 (the intermediate term supply curve for ethanol absent the Federal subsidy).

4.2.4.2

ETBE Long Term Cost Estimates Without Tax Credit

Determining the long term supply curve for ETBE without the ethanol subsidy requires reading off the already-established long term price curve for unsubsidized ethanol (see Appendix M, Table M-6).

The first block of ETBE supplied to California is assumed to be based in Canada. This includes the 19,000 b/d of new capacity coming on line (see Appendix A, Table A-1), for a total of 37,000 b/d of ether capacity in Canada. The first 7,700 b/d of ethanol required as feedstock for this ETBE capacity is supplied from the Caribbean at a delivered cost of 83 cents/gallon, and volumes above this are delivered from the Midwest at a transportation cost of 15 cents/gallon. The transportation cost for finished ETBE delivered from Canada to California is 3 cents/gallon.

The remainder of ETBE delivered to California is supplied from ether capacity in the Gulf Coast. Ethanol input costs to the Gulf Coast are also read off the long term supply curve for ethanol, and an 8 cent/gallon transportation cost is added to the delivered cost of ethanol in the Gulf Coast. A 9 cent/gallon transportation cost is added to the delivered cost of ETBE from the Gulf Coast to California (including the surcharge for water soluble materials).

There is no ether production tied up in the long term, as more MTBE facilities can be built in the long term, or cheaper MTBE can be imported. See Appendix M, Table M-10 for price/volume relationships.

4.3

TAME Use in California (MTBE Ban in California Only)

Only the intermediate supply curve for TAME delivery to California needs to be considered. Long term supply is determined in the refinery modeling conducted for the “mixed oxygenate case” for the various scenarios in the overall study.

There are no policy assumptions other than a ban on MTBE that would affect the supply curve for TAME.

4.3.1

California’s TAME Requirements

TAME contains about 15.7% oxygen, and about 12.4% TAME is needed in a gallon of gasoline to achieve the 2.0 wt. % oxygen target. This study assumes that California consumes on average about 965,000 b/d of gasoline in the intermediate term. The amount of TAME needed under the current regulations *for oxygen purposes only (not volume)* is therefore about 120,000 b/d to achieve a 2.0 wt. % oxygen level, and 161,000 b/d to achieve a 2.7 wt. % oxygen level. In the long term, California is assumed to demand 1.022 million b/d of gasoline. The amount of TAME needed at this demand level is about 127,000 b/d to achieve a 2.0 wt. % oxygen level, and 171,000 b/d to achieve a 2.7 wt. % oxygen level.

4.3.2

TAME Availability

As stated in Section 2.4, the U.S. currently has capacity to produce about 23,000 b/d of TAME. In addition, there is about 24,000 b/d of TAME capacity outside the U.S. Capacity can only be increased by building new TAME units at refineries that do not currently have units. Additional TAME capacity in the long term will be determined by the refinery modeling conducted for the “mixed oxygenate case” for various scenarios in this study. These additional supplies will come from the U.S. or abroad, as estimated through refinery modeling.

4.3.3

TAME Cost Estimates

The supply curve analyzed below is found in Appendix M, Table M-11.

4.3.3.1

TAME Cost Estimates, Intermediate Term

As explained above, TAME is feedstock limited, and existing capacity cannot be expanded. In the intermediate term, therefore, the supply curve is bounded at 47,000 b/d, which represents the total capacity available in the world.

In the intermediate term, California CARB RFG blenders would have to outbid other users of the limited volumes of TAME in order to secure oxygenate supply and comply with California and Federal oxygen regulations. A breakeven price for TAME needs to be determined, above which current users of TAME will switch to alternate oxygenates such as MTBE, ethanol, etc.

In order to make these breakeven comparisons, TAME needs to be valued correctly.

TAME's value will depend on the cost of MTBE, the cost of pool gasoline, and the cost of octane and RVP. Using a volume percentage of TAME and MTBE that averages the amount needed to reach a 2.0 wt % oxygen level (12.4% and 11.0% respectively) and the amount needed to reach a 2.7 wt. % oxygen level (16.7% and 14.8% respectively), TAME's value can be expressed using the following equation[4]:

$$P_{TAME} = (.871P_{B\text{-}MTBE} - .8545P_{B\text{-}TAME} + .129P_{MTBE})/0.1455$$

Where

P_{TAME} = Price of TAME
$P_{B\text{-}MTBE}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with MTBE
$P_{B\text{-}TAME}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with TAME
P_{MTBE} = Price of MTBE

In order to determine the relevant price/volume relationships for TAME supply, blocks of outside supply are identified, and breakeven TAME values are determined to attract these volumes away from their markets. Transportation costs are then added from the various regions around the world that have TAME capacity and could ship the product to California. Those regions are: the U.S. Gulf Coast and East Coast, Europe (both Northwest Europe and the Mediterranean), the Caribbean, and South Africa.

The first volume of TAME supplied to California is 5,100 b/d of TAME produced within the California refining system. This TAME is valued at 85.3 cents/gallon, using an MTBE price of 89.4 cents/gallon and a pool gasoline price of 69.6 cents/gallon.

The second block of TAME supplied to California is roughly 7,100 b/d produced in Europe. This TAME is valued at 77.3 cents/gallon, based on an MTBE price of 81.9 cents/gallon and a pool gasoline price of 56.5 cents/gallon. The price of MTBE and pool gasoline in Europe was determined by applying a differential (taken from ESAI's price database) to the Gulf Coast pool gasoline and MTBE prices used in this study. A transportation cost of 8.2 cents/gallon and 8.9 cents/gallon were used for delivery of TAME to California, depending on TAME production locations in Northwest Europe or Mediterranean Europe.

[4] This equation is similar to the equation used in Section 4.1.3.1, which is derived in Appendix B. The co-efficients have been set up for blending with TAME instead of ethanol.

Approximately 9,400 b/d of TAME will be supplied to California through the Caribbean. This TAME is valued at 80.9 cents/gallon, based on Gulf Coast MTBE and pool gasoline prices of 85.4 cents/gallon and 62 cents/gallon.

The Gulf Coast will provide up to 15,600 b/d of TAME, at a cost of 80.9 cents/gallon, based on an MTBE price of 85.4 cents/gallon and a pool gasoline price of 62 cents/gallon.

Approximately 1,500 b/d of TAME will be available from Asia. TAME is valued at 84.5 cents/gallon, based on MTBE and pool gasoline prices of 89.4 cents/gallon and 62.1 cents/gallon. Approximately 2,600 b/d of TAME will be supplied from the U.S. East Coast (Delaware), at a cost of 84.6 cents/gallon, based on MTBE and pool gasoline prices of 89.4 cents/gallon and 63.5 cents/gallon. Finally, South Africa can provide up to 5,600 b/d of TAME, at a cost of 84.7 cents/gallon, based on MTBE and pool gasoline prices of 89.4 cents/gallon and 64 cents/gallon.

Since TAME is produced by refineries in relatively small volumes for internal use, rather than merchant sales, handling and transportation costs are relatively high compared to oxygenates that are produced for merchant sales. A 10 cent/gallon handling/shipping surcharge was added to TAME's delivery price to California in order to ensure that TAME is not delivered cheaper than the base case for MTBE delivery to California, as TAME is not presently imported into the state.

The price/volume relationships and transportation costs are shown below:

Region	**Volume of TAME (b/d)**	**TAME value (cents/gallon)**	**Transportation and handling to California (cents/gallon)**	**Delivered price TAME to California (cents/gallon)**
California	5,100	85.31	10	95.31
NWE	2,300	77.19	18.2	95.39
Med	4,784	77.25	18.9	96.15
Caribbean	9,350	80.94	15.7	96.64
Gulf Coast	15,610	80.91	18	98.91
Taiwan	1,500	84.47	17	101.47
Delaware	2,572	84.63	20	104.63
South Africa	5,603	84.68	20	104.68
TOTAL	46,819			

4.4

TBA (MTBE Ban in California Only)

The intermediate and long term supply curves for TBA delivered to California are described below. There are no policy assumptions other than a ban on MTBE that would affect the supply curve for TBA

4.4.1

California's TBA Requirements

TBA contains about 21.6% oxygen, and about 8.8% TBA is needed in a gallon of gasoline to achieve the 2.0 wt. % oxygen target. This study assumes that California consumes on average about 965,000 b/d of gasoline in the intermediate term. The amount of TBA needed under the current regulations *for oxygen purposes only (not volume)* is therefore about 85,000 b/d to achieve a 2.0 wt. % oxygen level, and 114,000 b/d to achieve a 2.7 wt. % oxygen level. In the long term, California is assumed to demand 1.022 million b/d of gasoline. The amount of TBA needed at this demand level is about 90,000 b/d to achieve a 2.0 wt. % oxygen level, and 121,000 b/d to achieve a 2.7 wt. % oxygen level.

4.4.2

TBA Availability

As stated in Section 2.5, there is nearly 60,000 b/d of TBA capacity in the world, with nearly 35,000 b/d located in the U.S. Most of this production is associated with propylene oxide production, and most (except for some chemical use) is currently converted to MTBE due to MTBE's higher octane value. TBA capacity can be increased by either converting MTBE units to TBA units or building new TBA units, although conversion of MTBE units is a more economic solution.

During the intermediate term, it is assumed that all MTBE units can be converted to TBA production, except for ether units in California, which are assumed to produce MTBE and TAME for blending in gasoline exported to Arizona and Nevada.

4.4.3

TBA Cost Estimates

The supply curves analyzed below are found in Appendix M, Tables M-12 M-13.

4.4.3.1

TBA Cost Estimates Intermediate Term

TBA production that exists today is mostly used for conversion to MTBE, as MTBE has a higher octane value. It is assumed that existing TBA plants would supply California with TBA if it were just as or more profitable to produce TBA as a final product instead of MTBE. In addition, California blenders will bid away TBA from those ether plants that have converted to TBA production by bidding the price of TBA above a breakeven level with other oxygenates. The intermediate supply curve for TBA delivered to California is therefore based on the prices required to induce existing TBA/MTBE plants to switch from MTBE to TBA production, and to bid away converted volumes from other blenders.

The first volumes of TBA supplied to California on the supply curve will be from the 18,000 b/d of MTBE production in Canada that would be converted to TBA production. TBA is 20% denser than MTBE, so that the 18,000 b/d of MTBE capacity will produce roughly 14,400 b/d of TBA. Using a volume percentage of TBA and MTBE that averages the amount needed to reach a 2.0 wt % oxygen level (8.8% and 11.0% respectively) and the amount needed to reach a 2.7 wt. % oxygen level (11.8% and 14.8% respectively), TBA's value can be expressed using the following equation[5]:

$$P_{TBA} = (.872P_{B\text{-}MTBE} - .897P_{B\text{-}TBA} + .129P_{MTBE})/0.103$$

Where

P_{TBA} = Price of TBA
$P_{B\text{-}MTBE}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with MTBE
$P_{B\text{-}TBA}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with TBA
P_{MTBE} = Price of MTBE

Using this equation, and the inputs of 85.4 cents/gallon for MTBE and 62 cents/gallon for pool gasoline, Canadian-produced TBA is valued at 80.6 cents/gallon. A transportation cost of 3 cents/gallon is assessed for delivery to California.

The second block of TBA supplied to California on the supply curve will be from approximately 66,000 b/d of MTBE production in the U.S. Gulf Coast that would presumably be converted to 55,000 b/d of TBA production. Using the equation above, with the inputs of 85.4 cents/gallon for MTBE and 62 cents/gallon for pool gasoline, Gulf Coast-produced TBA is valued at 84.6 cents/gallon. An 8 cent/gallon transportation cost is assessed for TBA delivered from the Gulf Coast to California.

The third block of TBA supplied to California on the supply curve will be volumes of MTBE production in the U.S. Gulf Coast that would be converted to TBA production. Using the equation above, with inputs of 85.4 cents/gallon for MTBE and 62 cents/gallon for pool gasoline, Gulf Coast produced TBA is valued at 84.1 cents/gallon, and delivered to California with an 8 cent/gallon transportation charge.

A value for TBA was derived for each region that could *currently* supply TBA as a finished product instead of upgrading it to MTBE (existing TBA/MTBE plants in Northwest Europe, Mediterranean, U.S. Gulf Coast, Russia). The TBA value was derived by estimating the

[5] This equation is similar to the equation used in Section 4.1.3.1, which is derived in Appendix B. The co-efficients have been set up for blending with TBA instead of ethanol.

market value required to make TBA more valuable as a finished product than it would be as a feedstock for MTBE production. The equation used for converting TBA to MTBE is as follows, on a liquid volume basis[6]:

0.8 TBA + 0.34 methanol = 1 MTBE

With this equation, TBA's value is tied to the market value of MTBE and methanol. For the purposes of this study, different MTBE values were used for each region that produces TBA, while methanol prices were held constant (61.2 cents/gallon), due to a lack of publicly available international data on methanol prices. In this way, a breakeven price of TBA for TBA production around the world was determined, and a freight cost was added to arrive at a delivered cost to California.

Thus, the next available block of TBA available to California on the supply curve will be 21,000 b/d of TBA produced in Europe. The MTBE price in Europe used for this study is 81.9 cents/gallon, which is the Gulf Coast price (85.4 cents/gallon) minus a differential based on ESAI's price database. In addition, a 10 cent/gallon handling/transportation cost is assigned TBA, due to the fact that TBA is presently produced for internal use (upgrading to MTBE), rather than merchant sales. It is assumed that, similar to the case of TAME production, handling and transport costs will be higher than the case of volumes of MTBE sold by a merchant producer. Using the above equation that ties TBA's value to MTBE and methanol, TBA will be available from Europe at 84.6 to 85.3 cents/gallon, depending on the transportation cost from Northwest Europe or the Med Europe.

The remaining supply of TBA delivered to California will originate from existing TBA production in the U.S. Gulf Coast. Using a Gulf Coast MTBE price of 85.4 cents/gallon, TBA would be valued at 84 cents/gallon, and delivered to California at $1.02/gallon.

The price/volume relationship for existing TBA production is as follows:

TBA supply region	**TBA capacity (volume available)**	**MTBE value (cents/gallon)**	**TBA value (cents/gallon)**	**Transportation and handling cost to California (c/g)**	**Delivered cost to California (c/g)**
Canada (converted)	14,400	85.4	80.6	3	83.6
Gulf Coast (converted)	54,600	85.4	84.1	8	92.1
NW Europe	10,400	81.9	76.4	18.2	94.6
Med Europe	10,600	81.9	76.4	18.9	95.3
US Gulf Coast	34,800	85.4	80.7	18	98.7

Again, the Gulf Coast price of MTBE is assumed to be unaffected in this scenario, since the decline in demand is met barrel for barrel by the decline in supply (as MTBE is converted to TBA production).

[6] This equation supplied by ARCO Chemical Company.

4.4.3.2

TBA Cost Estimates Long Term

Estimates of long term TBA supply costs are based on MTBE production economics, which are very similar to TBA production economics. The difference is that TBA operating costs are higher by 20%, due to the fact that for every barrel of MTBE produced, only 0.8 barrels of TBA are produced.

The long term supply curve for TBA was constructed by taking the production costs from the long term MTBE supply curve base case, and factoring in a 20% increase in operating costs. Long term TBA supply is assumed to come from areas such as Canada and the Middle East that have low-cost MTBE/TBA production economics. At the higher end of the supply curve, existing TBA production in the U.S. Gulf Coast will supply TBA to California based on the equation explained above (0.8 TBA + .34 Methanol = 1 MTBE). The extra 10 cent/gallon transportation/handling surcharge is not assumed to be present in the long run.

Section 5.

SCENARIO: *MTBE BANNED IN UNITED STATES*

SUPPLY COST ESTIMATES FOR ALTERNATIVE OXYGENATES

The second scenario in this study posits that MTBE is banned not only in the state of California, but nation-wide. Different policy assumptions under this scenario are then examined with respect to their effect on the cost of alternative oxygenates within the marketplace. With the exception of the policy assumption of HR630 passing (which would allow California refiners the option of using no oxygenate at all during the summer season), other oxygenates are needed by California refiners to comply with federally and state mandated minimum oxygen levels in CARB RFG.

The supply curves examined below are estimates of the cost of alternate oxygenates delivered to California in the event of a nation-wide ban on MTBE. As in the case of a California ban only, the cost of the following alternate oxygenates will be analyzed: ethanol, ETBE, TAME, and TBA. And, as in the case of a California ban only, the only policy assumptions (or combination of policy assumptions) that would have an impact on the shape of the supply curves will be those involving removal of tax credits for ethanol and ETBE. This is because while HR 630 may reduce the ultimate volume of oxygenate (whether MTBE, ethanol, ETBE, etc), it will not change the slope of the supply curve. Likewise, granting ethanol a 1 psi RVP waiver may result in a higher amount of ethanol consumed in California, but it will not change the slope of the supply curve. Since tax credit issues change the ultimate price of ethanol and ETBE, this is the only policy assumption that will result in a different supply curve for these oxygenates.

The refinery model used in this study allows for California ether capacity to be converted to ETBE and TBA production under the scenario of a U.S.-wide ban of MTBE.

5.1

Ethanol Use in California (U.S. MTBE Ban)

Two sets of supply curves need to be considered for the alternative oxygenate ethanol. The first set of supply curves considered will represent the price of ethanol with current tax regulations in place (i.e., gasoline blenders are eligible for up to a $.54/gallon tax credit for ethanol in blends of up to 10%, and a pro-rated tax credit for blends of less than 10%, such as 7.7% and 5.7%), both for the intermediate term and the long term. The second set of supply curves will represent the price of ethanol without the tax credit, both for the intermediate term and the long term.

5.1.1

U.S. and California Ethanol Requirements (U.S.-Wide MTBE Ban)

California's ethanol requirements in the case of a U.S.-wide ban of MTBE are the same as in the case of a California-only ban of MTBE.

5.1.2

Ethanol Availability in the U.S. and the World

Currently, the U.S. produces about 80,000 b/d of ethanol, and imports an small amount occasionally from Central America. We estimate the current on-line capacity in the U.S. and Canada to be about 111,000 b/d. Therefore, ethanol producers are only producing at about 70% of capacity and there is about 30,000 b/d of spare capacity that can be used to supply the country.

Brazil is the largest producer of ethanol in the world, and has a capacity of about 260,000 b/d. However, the U.S. would be unable, under present circumstances, to import much ethanol from Brazil. Brazil has mandated that all gasoline sold in the country contain 24% ethanol. Brazil's average gasoline consumption is about 300,000 b/d, and therefore the amount of mandated ethanol use is 66,000 b/d. In addition, however, 4 million of Brazilian cars are built to run on 100% ethanol (hydrous ethanol). The ethanol used to fuel these cars must therefore be considered dedicated ethanol, or ethanol that cannot be pulled from Brazil for use outside the country. This amounts to about 148,000 b/d of dedicated ethanol supply.

Therefore, in reality, there is very little Brazilian ethanol that can be supplied to the U.S. market, since 214,000 b/d (148,000 b/d + 66,000 b/d) is currently dedicated or mandated for use in Brazil. During the immediate term, at most about 30,000 b/d of surplus ethanol could presently be supplied to the U.S. market as surplus Brazilian ethanol. While the number of cars running on 100% ethanol in Brazil is declining, overall gasoline consumption has been rising very rapidly, approaching close to 10% growth in 1997. Therefore, lower ethanol use in Brazil by dedicated vehicles is being offset to a large degree by the growth of the gasoline pool. In addition, foreign ethanol that is not considered under the Caribbean Basin Initiative exemption is currently subject to a 54 cent/gallon tariff. This tariff is presumed to remain in place for the purposes of this study.

France, Italy, and Spain together produce about 30,000 b/d of excess wine ethanol from their combined wine industries. This ethanol, however, would also be subject to the tariff of $.54/gallon applied against foreign produced biomass ethanol. So would other beverage grade ethanol, available in Asia and the FSU.

There are also quantities of synthetic ethanol available on the world market. However, this ethanol would not be eligible for the tax credit, as it is not a biomass fuel, and would need to be diverted from its end use as chemical feedstock.

5.1.3

Ethanol Cost Estimates (U.S. Ban of MTBE)

The price/volume relationships analyzed below are found in Appendix M, Table M-14 and M-15. It is assumed that all subsidies including tax credits for blenders are in place throughout the country.

5.1.3.1

Ethanol Cost Estimates, Intermediate Term, U.S. Ban on MTBE

The U.S. consumes on an annual basis approximately 2.7 million b/d of reformulated gasoline, and approximately 230,000 b/d of oxygenated gasoline for wintertime carbon monoxide programs. Excluding California, which in the intermediate term is assumed to demand 965,000 b/d of reformulated gasoline in this study, the U.S. consumes 1.71 million b/d of RFG. Excluding Minnesota, which consumes 79,000 b/d of oxygenated gasoline due to its year-round 2.7 wt. % oxygen requirement, the U.S. consumes approximately 154,000 b/d of oxygenated wintertime gasoline. Thus, in the event of a U.S. ban on MTBE, the U.S., excluding California and Minnesota, would need to find enough oxygen to satisfy about 1.86 million b/d of gasoline that needs to be either oxygenated for reformulation purposes or for wintertime oxygen purposes.

In order to accommodate a sensitivity for the refining modeling section of the study that assumes California gasoline blenders can blend ethanol up to a 3.5 wt. % oxygen level, the supply curve for ethanol delivered to California must supply up to nearly 100,000 b/d of ethanol (965,000 b/d of gasoline at 3.5 wt. % oxygen is equivalent to a 10% ethanol blend, or 96,500 b/d of ethanol).

In the event of a U.S.-wide ban of MTBE, gasoline blenders outside of California will see ethanol as a substitute for MTBE. Therefore, in the intermediate term, California will need to compete for this limited ethanol supply with these outside blenders. As ethanol is bid above its breakeven value, outside blenders will seek other substitutes, such as TAME and TBA. Presumably, MTBE capacity will be converted to TBA output in order to supply this demand.

In order to make these breakeven comparisons, ethanol needs to be valued correctly. In Section 4.1.3.1 (ethanol delivered to California in the intermediate term under a California only ban of MTBE), breakeven values were calculated for blenders of ethanol within each state. Ethanol's value depended on whether it was being used as an oxygenate in oxygenated gasoline in that state, or whether it was being blended in gasohol as a gasoline extender.

In this section, a similar calculation is made. Instead of determining breakeven values needed to bid ethanol away from ethanol blenders in each state, breakeven values are calculated to determine the price necessary to outbid non-Californian blenders of RFG and oxygenated wintertime gasoline. In the case of a U.S. ban on MTBE, gasoline blenders outside California will be seeking alternate oxygenates in the marketplace to satisfy their oxygen blending requirements. These blenders will value ethanol as an oxygenate, and will bid ethanol prices above the typical Midwest gasohol value. Therefore, in order to secure delivery of ethanol to California, blenders in California will need to bid ethanol above the breakeven oxygenate value for each outside blender of RFG or wintertime oxygenated gasoline.

In Section 4.1.3.1, ethanol's value as an oxygenate depended on the cost of MTBE, the cost of octane and Reid Vapor Pressure (RVP). In this case, however, MTBE has been banned, eliminating it as a useful benchmark against which to price ethanol. Ethanol's value will be determined, therefore, by other substitutable oxygenates, such as TAME and TBA.

The value of TAME and TBA can be assumed to be equal to MTBE's market value (85.4 cents/gallon in this study), minus an adjustment for octane differences. Using an octane price of 0.7 cents/octane number, TAME is worth 3.5 cents/gallon less than MTBE (MTBE's octane level of 110 minus TAME's octane level of 105 multiplied by the octane price). TBA is worth 7 cents/gallon less than MTBE (MTBE's octane level of 110 minus TBA's octane level of 100 multiplied by the octane price). TAME's market value is therefore calculated as 81.9 cents/gallon, and TBA's value is calculated as 78.4 cents/gallon. In addition, a 4 cent/gallon differential was added to the TBA/TAME price in Padds I, II, IV, and V to account for similar differentials from Gulf Coast prices that exist today in the MTBE market.

With a benchmark value against which to value ethanol (the averaged price of TAME and TBA), breakeven prices can be calculated by RFG or oxygenated gasoline areas around the U.S.

To determine the breakeven level for ethanol in states requiring RFG gasoline the following equation is used, with the co-efficients set up to account for the volumes of ethanol and TBA/TAME required to achieve a 2.0 wt. % oxygen level [7]:

$$P_{EOH} = (0.894\ P_{B\text{-}TAME/TBA} - 0.943\ P_{B\text{-}EOH} + 0.106\ P_{TAME/TBA} - C_{EOH})/0.057$$

Where

P_{EOH} = Price of ethanol
$P_{B\text{-}TAME/TBA}$ = Averaged price of reformulated blendstock for oxygenate blending (RBOB) with TAME and TBA.
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with ethanol
$P_{TAME/TBA}$ = Averaged price of TAME and TBA

[7] This equation is similar to the equation used in Section 4.1.3.1, which is derived in Appendix B. In this equation and the one following it, the co-efficients for TBA/TAME is an average of the volumes required to blend TBA and TAME to a 2.0 wt. % oxygen level, or a 2.7 wt. % level.

C_{EOH} = Any costs associated with blending ethanol

In states where oxygen is needed for blending in wintertime oxygenated gasoline, a similar equation is used, with the co-efficients set up to account for the volumes of ethanol and TBA/TAME required to achieve a 2.7 wt. % oxygen level:

$$P_{EOH} = (0.858\ P_{B\text{-}TAME/TBA} - 0.923\ P_{B\text{-}EOH} + 0.143\ P_{TAME/TBA} - C_{EOH})/0.077$$

The price of the RBOBs used in the above equations is dependent on the price of pool gasoline (see Appendix B for derivation). Since gasoline prices differ in each state, ethanol will be valued differently according to its gasoline market. Rack gasoline price data from the U.S. Energy Information Agency's *Petroleum Marketing Annual* publication were used to determine gasoline prices for all states that consume reformulated or oxygenated gasoline. Prices were adjusted for use in this study by basing them on the price of pool gasoline used in the study (62 cents/gallon) and then adding a differential based on the relative prices found in each state. For example, Indiana's rack price for gasoline was 1.5 cents/gallon higher than that of Mississippi, which had the lowest U.S. rack price; therefore, for the purposes of this study, the pool price for Indiana is 63.5 (62 plus 1.5).

Using the formulas expressed above, breakeven ethanol values were determined for each state that blends oxygen for RFG or oxygenated gasoline. The state-level incentives for ethanol use that exists in several states, namely South Dakota, Ohio, Missouri, and Illinois, does not effect the breakeven ethanol values here, since the oxygenate breakeven values rise above the gasohol break even values, even with the additional incentives factored in.

Using historical data for RFG and oxygenated gasoline sales in each state (source: U.S. Energy Information Agency 1997 *Petroleum Marketing Annual*), it is possible to determine the volume of ethanol that would be required to satisfy each state's oxygen requirement. Volumes of reformulated gasoline were multiplied by 5.7% to calculate potential ethanol volumes demanded for RFG gasoline at 2.0 wt. % oxygen level. Volumes of oxygenated gasoline were multiplied by 7.7% to calculate potential ethanol volumes demanded for oxygenated gasoline at 2.7 wt. % oxygen level.

The potential ethanol volumes (b/d) demanded by each state that requires RFG or oxygenated gasoline and price (cents/gallon) at which ethanol would be valued in each state are listed below:

State	**RFG Demand**	**Oxygenated Mogas demand**	**Potential Ethanol Demand**	**Ethanol Value**
New Mexico		7,688	592	84.7
Utah		2,388	184	86.8
Nevada		16,338	1,258	88.1
Montana		590	45	88.2
Oregon		22,114	1,703	91.0
Arizona	75,714	23,933	6,159	92.0
Washington		36,350	2,799	92.2
Colorado		33,455	2,576	93.6
Texas	282,040	8,243	16,711	95.2
New Hampshire	22,443		1,279	98.3

Connecticut	88,933	5,069	98.5
Rhode Island	35,693	2,034	98.6
Massachusetts	170,648	9,727	98.9
New Jersey	265,057	15,108	98.9
Maine	32,076	1,828	99.2
New York	192,302	10,961	100.2
Delaware	24,671	1,406	100.8
Illinois	169,755	9,676	101.1
Maryland	118,507	6,755	101.4
Wisconsin	43,902	2,502	101.5
Kentucky	31,071	1,771	101.7
Pennsylvania	89,138	5,081	101.8
Indiana	25,110	1,431	102.5
Virginia	129,588	7,387	102.6

The supply curve for ethanol delivered to California under a U.S.-wide ban of MTBE is built up by using the above volumes, which represent the amount of ethanol that blenders outside California would potentially demand unless the price was bid above a level at which they value ethanol.

Even if 100,000 b/d of ethanol was bid away from the rest of the country by California (in the case of the entire state blending to a 3.5 wt. % oxygen level), the rest of the U.S. could satisfy its oxygen requirements by a combination of leftover ethanol capacity, TAME, TBA, and additions to ethanol capacity.

U.S. RFG demand excluding California is estimated at about 1.71 million b/d. U.S. oxygenated gasoline demand excluding Minnesota is estimated at about 154,000 b/d. With up to 100,000 b/d of ethanol delivered to California, this would leave 11,000 b/d of spare capacity plus 7,700 b/d of ethanol imported from the Caribbean, for a total of about 19,000 b/d. This would account for approximately 328,000 b/d of RFG gasoline demand at 2.0 wt. % oxygen level (5.7% ethanol). Total world TAME capacity of nearly 47,000 b/d would account for approximately 378,000 b/d of RFG demand at 2.0 wt.% oxygen level (12.4% TAME). And total world TBA capacity of nearly 60,000 b/d would account for approximately 677,000 b/d of RFG demand at 2.0 wt.% oxygen level (8.8% TBA). Total RFG demand satisfied by these remaining oxygenates equals 1.38 million b/d, leaving 327,000 b/d of US RFG demand. In addition U.S. oxygenated gasoline demand (154,000 b/d) remains unsatisfied.

The remaining RFG demand of 327,000 b/d would require 19,000 b/d of ethanol at 2.0 wt.% oxygen level, while oxygenated gasoline demand of 154,000 b/d would require 12,000 b/d of ethanol at 2.7 wt.% oxygen level. It is assumed that this 31,000 b/d of ethanol capacity required to satisfy the remainder of U.S. oxygen requirements could be supplied by additions to existing ethanol capacity. The larger ethanol producers would most likely be the best candidates for this type of expansion, and would add to capacity as the price of ethanol increased, according to the supply curve.

5.1.3.2

Ethanol Cost Estimates, Long Term, U.S. Ban on MTBE

The methodology for determining the long term supply curve for ethanol under the U.S.-wide MTBE ban is similar to the case of the long term supply curve under a California-only ban, as explained in Section 4.1.3.2. In addition to the ethanol projects already planned, new producers will enter the market in the long term, attracted by higher prices for ethanol in the intermediate term and increased demand caused by a switch to ethanol consumption in California and the U.S. during the intermediate term.

The long term scenario assumes that the entire country uses ethanol in addition to the approximately 58,000 b/d to 102,000 b/d that would be produced to supply California's needs. Assuming that approximately 91% of ethanol will continue to be processed with corn feedstock, and that approximately 2.6 gallons of ethanol are produced from a bushel of corn, this increased demand will require additional feedstocks of 311 to 547 million bushels of corn per year.

In a long term time period, this additional corn can be expected to be supplied in response to demand. Additional corn production is expected to respond to the long term supply elasticity of price for corn (the percentage change in corn price divided by the percentage change in supply of corn), as explained in Section 4.1.3.2. Using this elasticity value of 0.3, prices for corn were calculated at various volumes of ethanol supplied to the market. For the purposes of this study, a baseline of $2.60/bushel was used.

In addition, bio-mass ethanol from other agricultural sources would probably be used. Since very little commercial capacity of bio-mass production exists today, and thus very little data on production costs are available, it is assumed that the production costs will be similar to corn-based ethanol.

As in Section 4.1.3.2, additional ethanol production is expected to result in a large increase in the supply of by-products, such as distiller's dried grains (DDG), gluten feed and gluten meal. It expected that the price of these by-products will decline in response to the long term supply elasticities for these products. The same byproduct elasticities used in Section 4.1.3.2, are used in this section.

Using these figures, it is possible to calculate supply elasticities for the by-products of ethanol production, and therefore determine the price of DDG, gluten feed, and gluten meal at various volumes of ethanol supplied to the market in the long term.

By determining the long term price of corn and the long term price of ethanol by-products, net production costs are calculated at various volumes of ethanol. All other fixed and variable costs besides corn cost and by-product prices were held constant.

In the long term scenario, ethanol prices are expected to decline to their marginal cost of production as calculated above. Since most production will still be located in the large corn-producing states, the transportation cost of 15 cents/gallon remains.

The calculations for determining the long term costs of corn and by-products are shown in Appendix J, and the formulas for determining the production costs for ethanol producers is explained in Appendix E.

5.1.4

Loss of Tax Credit

The following section estimates intermediate and long term cost of ethanol delivered to California in the absence of Federal subsidy, in the form of a 54 cent/gallon of ethanol tax credit.

The approach used for determining the supply curve for ethanol delivered to California in the absence of a Federal subsidy is to estimate the pattern of supply and use of ethanol, given the loss of the ethanol tax and with no California ban of MTBE, i.e., the current regulatory situation, but with no ethanol tax break. As is explained below, this study assumes that little or no ethanol use will continue. The supply curve for delivery of ethanol to California is then constructed by estimating the price necessary to induce ethanol plants to resume operation.

5.1.4.1

Ethanol Intermediate Term Cost Estimates: No Tax Credit, U.S. Ban on MTBE

In the event of a U.S.-wide ban of MTBE, blenders outside California would look to alternate oxygenates such as ethanol, TBA and TAME to satisfy their oxygen requirements. As explained in Section 5.1.3.1 (ethanol delivered to California with tax credits available and a U.S. ban of MTBE), California blenders will compete with blenders outside the state of California for ethanol supplies. In Section 5.1.3.1, the price was bid to a breakeven level that was equal to ethanol's oxygenate value from state to state. As the price of ethanol was bid above this calculated breakeven price, blenders outside California turned to TBA and TAME as alternatives, leaving ethanol to be delivered to California.

In this case, without the federal 54 cent/gallon subsidy, ethanol will not be produced unless its price rises above production costs. As explained in Section 4.1.4.1, these production costs can be expected to vary state-by-state depending on corn costs found in each state. In general, these ethanol production costs will be higher than the cost of the alternative oxygenates, TBA and TAME. Thus, as the price of ethanol rises to its production costs, blenders outside California will turn to TBA and TAME before ethanol, as TBA and TAME will be cheaper.

The methodology for constructing the supply curve for ethanol delivered to California absent the federal subsidy under a U.S. ban of MTBE results in the same curve as ethanol delivered to California absent the federal subsidy under a California-only ban of MTBE. Under a U.S. ban of MTBE, blenders outside California requiring oxygenates for oxygenated or RFG gasoline will use a combination of TAME, TBA and ethanol. These outside blenders will consume TBA and TAME first, as the cost for these oxygenates will be lower than the price that ethanol must reach in order to induce production from even the lowest cost producers.

Therefore, the supply curve for unsubsidized ethanol under a U.S.-wide ban of MTBE is identical to that of unsubsidized ethanol under the California-only ban of MTBE. Due to the fact that under a U.S.-wide ban of MTBE, blenders outside California can satisfy their oxygen requirements with a combination of TBA, TAME and ethanol, California blenders will only have to bid the price of ethanol up to its production costs in each ethanol-producing state in order to secure supplies.

5.1.4.2

Ethanol Long Term Cost Estimates: No Tax Credit, U.S. Ban on MTBE

In the event of a U.S.-wide ban of MTBE, blenders outside California would look to alternate oxygenates such as ethanol, TBA and TAME to satisfy their oxygen requirements. As explained in Section 5.1.3.1, California blenders will compete with these blenders outside California for ethanol supplies. In Section 5.1.3.1, the price was bid to a breakeven level that was equal to ethanol's oxygenate value from state to state. As the price of ethanol was bid above this calculated breakeven price, outside blenders turned to TBA and TAME as alternatives.

In this case, without the federal 54 cent/gallon subsidy, ethanol will not be produced unless its price rises above production costs. As explained in Section 4.1.4.1, these production costs can be expected to vary state-by-state depending on corn costs found in each state. In the long term, as explained in Section 4.1.4.2, it is expected that low-cost wet milling ethanol producers will migrate to low-cost corn regions.

In general, even ethanol production costs for wet milling producers in low-cost corn regions will be higher than the cost of the alternative oxygenates, TBA and TAME. Thus, as the price of ethanol rises to its production costs, blenders outside California will turn to TBA and TAME before ethanol, as TBA and TAME will be cheaper.

The methodology for constructing the long term supply curve for ethanol delivered to California absent the federal subsidy under a U.S. ban of MTBE results in the same long term curve as ethanol delivered to California absent the federal subsidy under a California-only ban of MTBE. Under a U.S. ban of MTBE, blenders outside California requiring oxygenates for oxygenated or RFG gasoline will use a combination of TAME, TBA and ethanol. These blenders outside California will consume TBA and TAME first, as the cost for these oxygenates will be lower than the price that ethanol must reach in order to induce production from even the lowest cost producers.

5.2

ETBE Use in California (U.S. MTBE Ban)

As in Section 4.2, which considered a California-only ban on MTBE, in the case of a U.S. ban on MTBE, two sets of supply curves need to be considered for the alternative oxygenate ETBE: that of ETBE delivered to California with the ethanol subsidy intact in the intermediate and long term, and that of ETBE delivered to California without the subsidy in the intermediate and long term. Since one of the main feedstocks for ETBE is ethanol, the supply curve for ethanol (both with and without the tax credit) must be used to determine the cost of different quantities of ETBE.

5.2.1

California's ETBE Requirements (U.S.-wide MTBE Ban)

California's ETBE requirements in the case of a U.S.-wide ban of MTBE are the same as in the case of a California-only ban of MTBE.

5.2.2

ETBE Availability

As stated in Section 2.2, the U.S. currently produces only a small quantity of ETBE, but capacity is estimated at about 53,000 b/d and could increase substantially if existing MTBE plants were converted to ETBE output. In addition, there is approximately 40,000 b/d of ETBE or MTBE/ETBE capacity outside North America. As explained below, however, it is unlikely that this foreign source of potential ETBE would be supplied to the California market.

The refinery model used in this study assumes that in the scenario of a U.S.-wide ban of MTBE, the 13,000 b/d of existing in-situ ether plants in California will be converted to manufacture ETBE.

5.2.3

ETBE Cost Estimates (U.S. Ban of MTBE)

As described below, intermediate and long term supply curves for ETBE delivery are dependent on intermediate and long term ethanol costs under the scenario of a U.S.-wide MTBE ban. The supply curves described in this section are found in Appendix M, Table M-18 and Table M-19.

5.2.3.1

ETBE Cost Estimates, Intermediate Term, U.S. Ban on MTBE

The first block of ETBE available to California blenders will be ETBE produced at ether plants at California refineries. The ethanol input cost is taken from the intermediate term supply curve for ethanol under a U.S.-wide MTBE ban (see Appendix M, Table M-16), with a 15 cent/gallon transportation cost added. The formula for determining ETBE's cost is the same as in previous sections (see Appendix D).

The second block of ETBE available to California will be ETBE produced from converted MTBE capacity located in Canada. A 15 cent/gallon transportation cost is assessed to the ethanol input cost, and a 3 cent/gallon transportation cost is added for ETBE delivered from Canada to California.

The rest of California's ETBE supplies will be produced in the U.S. Gulf Coast, where most U.S. ether capacity is located. An 8 cent/gallon transportation cost is added (Midwest to Gulf Coast) for the ethanol input cost, and a 9 cent/gallon transportation cost (Gulf Coast to West Coast) is added to reach the delivered cost of ETBE to California (this includes the 1 cent/gallon surcharge for water soluble materials).

Under a U.S.-wide ban of MTBE, blenders outside California are assumed to use a combination of TBA, TAME and ethanol for their oxygenate requirements. At present world capacity, TAME and TBA volumes can only supply part of U.S. oxygenate demand excluding California, requiring either additional TBA conversion from existing MTBE capacity, or additional ethanol production. It is assumed that as the price of ethanol rises, many of the larger ethanol producers will make additions to capacity in order to supply blenders outside California.

The resulting supply curve is located in Appendix M, Table M-18.

5.2.3.2

ETBE Cost Estimates, Long Term, U.S. Ban on MTBE

The long term supply curve for ETBE delivered to California under a U.S.-wide ban of MTBE uses the same methodology as the intermediate term curve. The ethanol input costs, however, are read from the long term supply curve for ethanol (U.S. ban of MTBE), which is located in Appendix M, Table M-17.

The first block of 13,000 b/d of ETBE will be supplied from Californian refineries, using converted MTBE capacity. The ethanol input cost is assessed a 15 cent/gallon transportation cost (Midwest to West Coast).

The second block supplied to California is produced by 37,000 b/d of ETBE capacity in Canada (this includes present capacity and the 19,000 b/d of capacity currently under construction, listed in Appendix A, Table A-2). The ethanol input cost for this block of ETBE is assessed at 15 cents/gallon, and a 3 cent/gallon transportation cost is added for delivery of ETBE from Canada to California.

The remaining ETBE supplied to California is produced in the Gulf Coast, from converted MTBE capacity. A transportation cost of 8 cents/gallon is assessed for the ethanol input cost (Midwest to Gulf Coast) and a transportation cost of 9 cents/gallon is assessed for ETBE delivered to California (this includes the 1 cent/gallon surcharge for water soluble materials).

The resulting supply curve is located in Appendix M, Table M-19.

5.2.4

Loss of Ethanol/ETBE Tax Credit

The supply curves (intermediate and long term) for ETBE delivered to California without the Federal subsidy under a U.S. ban of MTBE are very similar to the cases under a California-only ban of MTBE, as explained below.

5.2.4.1

ETBE Cost Estimates, Intermediate Term, U.S. Ban on MTBE, No Tax Credits

The intermediate term supply curve for ETBE without the Federal subsidy is the same as the intermediate term supply curve for ETBE under a California only ban of MTBE, with the exception of the first 13,000 b/d of ETBE supplied to California (which, in the U.S. ban scenario, is supplied by California ether plants converted to ETBE production). This is because the intermediate term supply curve for unsubsidized ethanol, which is an input to the ETBE curve, is the same for the case of the U.S. ban of MTBE as it is for the case of the California-only ban of MTBE (see Section 5.1.4.1).

The resulting supply curve is located in Appendix M, Table M-20.

5.2.4.2

ETBE Cost Estimates, Long Term, U.S. Ban on MTBE, No Tax Credits

The long term supply curve for ETBE without the Federal subsidy is the same as the long term supply curve for ETBE under a California only ban of MTBE, with the exception of the first 13,000 b/d of ETBE supplied to California (which, in the U.S. ban scenario, is supplied by California ether plants converted to ETBE production). This is because the long term supply curve for unsubsidized ethanol, which is an input to the ETBE curve, is the same for the case of the U.S. ban of MTBE as it is for the case of the California-only ban of MTBE (see Section 5.1.4.2).

The resulting supply curve is located in Appendix M, Table M-21

5.3

TAME Use in California (U.S. MTBE Ban)

Only the intermediate supply curve for TAME delivery to California needs to be considered. Long term supply is determined in the refinery modeling conducted for the “mixed oxygenate case” for the various scenarios in the overall study.

There are no policy assumptions other than a ban on MTBE that would affect the supply curve for TAME.

5.3.1

California’s TAME Requirements (U.S.-wide MTBE Ban)

California’s TAME requirements in the case of a U.S.-wide ban of MTBE are the same as in the case of a California-only ban of MTBE.

5.3.2

TAME Availability

As stated in Section 2.4, the U.S. currently has capacity to produce about 23,000 b/d of TAME. In addition, there is about 24,000 b/d of TAME capacity outside the U.S. Capacity can only be increased by building new TAME units at refineries that do not currently have units. Additional TAME capacity in the long term will be determined by the refinery modeling conducted for the "mixed oxygenate case" for various scenarios in this study. These additional supplies will come from the U.S. or abroad, as estimated through refinery modeling.

5.3.3

TAME Cost Estimates (U.S.-Wide MTBE Ban)

The supply curves analyzed below are found in Appendix M, Table M-22.

5.3.3.1

TAME Cost Estimates, Intermediate Term

As explained above, TAME is feedstock limited, and existing capacity cannot be expanded. In the intermediate term, therefore, the supply curve is bounded at 47,000 b/d, which represents the total capacity available in the world.

In the intermediate term, California CARB RFG blenders would have to outbid other users of the limited volumes of TAME in order to secure supply and comply with California and Federal oxygen regulations. A breakeven price for TAME needs to be determined, above which current users of TAME will switch to alternate oxygenates such as MTBE, ethanol, etc.

In order to determine the make these breakeven comparisons, TAME needs to be valued correctly.

The methodology for building the supply curve for TAME under a U.S.-wide ban of MTBE is similar to the supply curve for TAME under a California-only ban of MTBE; however, in this case, since MTBE is banned throughout the U.S., a value for MTBE cannot be used to determine the value of TAME.

TAME's value will therefore depend on the value of ethanol, which, due to its availability, will be sought for oxygenate purposes in the case of a U.S. wide ban of MTBE. Therefore, under a U.S. ban of MTBE, TAME's value in a breakeven analysis will depend on the cost of ethanol, the cost of pool gasoline, and the cost of octane and RVP. Using a volume percentage of TAME and ethanol that averages the amount needed to achieve a 2.0 wt. % oxygen level (12.4% and 5.7% respectively) and a 2.7 wt. % oxygen level (16.7% and 7.7% respectively), TAME's value can be expressed using the following equation [8]:

[8] This equation is similar to the equation used in Section 4.1.3.1, which is derived in Appendix B. The co-efficients have been set up for blending with TAME instead of ethanol.

$$P_{TAME} = (.933P_{B\text{-}EOH} - .8545P_{B\text{-}TAME} + .067P_{EOH})/0.1455$$

Where

P_{TAME} = Price of TAME
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with ethanol
$P_{B\text{-}TAME}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with TAME
P_{EOH} = Price of ethanol

In order to determine the relevant price/volume relationships for TAME supply, blocks of outside supply are identified, and breakeven TAME values are determined to attract these volumes away from their markets.

Blenders in the U.S. will be competing for ethanol and TAME. At some breakeven price level, these blenders will use ethanol instead of TAME. Using the blocks of TAME available in the U.S. and elsewhere, volumes of ethanol can be determined to represent the amount of ethanol a blender in the U.S. would require as an alternative to consuming TAME. For example, the 5,100 b/d block of TAME supplied from California would be roughly equivalent to 2,300 b/d of ethanol. On the intermediate supply curve for ethanol delivery to California under the case of a U.S. ban of MTBE, ethanol's value at 2,300 b/d is 91 cents/gallon (see Appendix M, Table M-16). Using this value for ethanol results in a price of 78.2 cents/gallon for TAME. Ethanol values are determined for each block of TAME supply, using the equivalent ethanol/TAME volume:

TAME demanded by CA (cumulative and incremental)

5,100	7,400	12,184	21,534	37,144	38,644	41,216	etc.
5,100	2,300	4,784	9,350	15,610	1,500	2,572	etc.

Ethanol equivalent volume and price

2,346	3,404	5,605	9,906	17,086	17,776	18,960	etc.
91.0	91.0	92.0	92.0	95.2	95.2	95.2	etc.

Resulting TAME value

78.2	78.2	78.7	78.7	80.1	80.1	80.1	etc.

Once ethanol values have been determined to calculate TAME values, the supply curve is constructed, using the appropriate transportation costs from the production source to California (these transportation costs are the same as in Section 4.3.3.1).

As explained in Section 4.3.3.1, these volumes will be delivered to California with a surcharge of 10 cents/gallon, since TAME is produced by refineries in relatively small volumes for internal use, rather than merchant sales, and therefore handling and transportation costs are relatively high compared to oxygenates that are produced for merchant sales.

5.4

TBA Use in California (U.S.-Wide MTBE Ban)

Only two supply curves (intermediate term and long term) need to be considered for the alternative oxygenate TBA. There are no policy assumptions other than a ban on MTBE that would affect the supply curve for TBA.

5.4.1

US and California's TBA Requirements (U.S.-Wide MTBE Ban)

California's TBA requirements in the case of a U.S.-wide ban of MTBE are the same as in the case of a California-only ban of MTBE.

5.4.2

TBA Availability

As stated in Section 2.5, there is nearly 60,000 b/d of TBA capacity in the world, with nearly 35,000 b/d located in the U.S. Most of this production is associated with propylene oxide production, and most (except for some chemical use) is currently converted to MTBE due to MTBE's higher octane value. TBA capacity can be increased by either converting MTBE units to TBA units or building new TBA units, although conversion of MTBE units is a more economic solution.

The refinery model used in this study assumes that in the scenario of a U.S.-wide ban of MTBE, the 13,000 b/d of existing in-situ ether plants in California can be converted to manufacture TBA.

5.4.3

TBA Cost Estimates (U.S.-Wide MTBE Ban)

The supply curves analyzed below are located in Appendix M, Table M-23 and M-24.

5.4.3.1

TBA Cost Estimates, Intermediate Term

TBA production that exists today is mostly used for conversion to MTBE, as MTBE has a higher octane value. In the intermediate curve under the scenario of a California-only ban of MTBE, it was assumed that that existing TBA plants would supply California with TBA if it were just as or more profitable to produce TBA as a final product instead of MTBE. In addition, California blenders could bid away TBA from those ether plants that had converted to TBA production by bidding the price of TBA above a breakeven level with other oxygenates. An equation was used for that scenario that tied the price of TBA to MTBE and methanol, or tied TBA's value to the cost of MTBE and cost of pool gasoline and octane.

The scenario of a U.S.-wide ban of MTBE is complicated by the fact that there cannot be a value for MTBE. Blenders in the U.S. will be competing for the remaining oxygenates--TBA, TAME and ethanol. TBA's value will probably depend on the cost of the most available alternate oxygenate, ethanol. Therefore, under a U.S. ban of MTBE, TBA's value in a breakeven analysis will depend on the cost of ethanol, the cost of pool gasoline, and the cost of octane and RVP. Using a volume percentage of TBA and ethanol that averages the amount needed to achieve a 2.0 wt. % oxygen level (8.8% and 5.7% respectively) and a 2.7 wt. % oxygen level (11.8% and 7.7% respectively), TAME's value can be expressed using the following equation[9]:

$$P_{TBA} = (.933P_{B\text{-}EOH} – .897P_{B\text{-}TBA} + .067P_{EOH})/0.103$$

Where

P_{TBA} = Price of TBA
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with ethanol
$P_{B\text{-}TBA}$ = Price of reformulated blendstock for oxygenate blending (RBOB) with TBA
P_{EOH} = Price of ethanol

Blenders in the U.S. will be competing for ethanol and TBA. At some breakeven price level, these blenders will use ethanol instead of TBA. Using the blocks of TBA available in the U.S. and elsewhere, volumes of ethanol can be determined to represent the amount of ethanol a blender in the U.S. would require as an alternative to consuming TBA. For example, the 10,200 b/d block of TBA from California (converted from 13,000 b/d of MTBE capacity) would be roughly equivalent to 6,600 b/d of ethanol. On the intermediate supply curve for ethanol delivery to California under the case of a U.S. ban of MTBE, ethanol's value at 6,600 b/d is 92 cents/gallon (see Appendix M, Table M-16). Using this value for ethanol results in a price of 77.4 cents/gallon for TBA. Ethanol values are determined for each block of TBA supply, using the equivalent ethanol/TBA volume (the first two blocks below represent TBA capacity in California and Canada, followed by 10,000 b/d increments of TBA capacity in the Gulf Coast):

TBA demanded by CA (cumulative and incremental)

10,160	24,560	34,560	44,560	54,560	64,560	74,560	84,560	etc.
10,160	14,400	10,000	10,000	10,000	10,000	10,000	10,000	etc.

Ethanol equivalent volume and price

6,604	15,964	22,464	28,964	35,464	41,964	48,464	54,964	etc.
92.0	95.2	95.2	95.2	98.5	98.9	98.9	98.9	etc.

Resulting TBA value

77.4	79.5	79.5	79.5	81.6	81.9	81.9	81.9	etc.

The supply curve is built up in this fashion, using the appropriate transportation costs from the production source to California.

[9] This equation is similar to the equation used in Section 4.1.3.1, which is derived in Appendix B. The co-efficients have been set up for blending with TBA against ethanol.

5.4.3.2

TBA Cost Estimates, Long Term

The long term supply curve for TBA under the scenario of a U.S.-wide ban of MTBE is identical to the case of the long term supply curve for the scenario of a California-only ban. In the long term, blenders outside of California are presumed to use ethanol, or TAME, and/or TBA for their oxygen requirements. California blenders are presumed not to compete with outside blenders for TBA as in the intermediate case scenarios.

Estimates of long term TBA supply costs are based on MTBE production economics, which are very similar to TBA production economics. The difference is that TBA operating costs are higher by 20%, due to the fact that for every barrel of MTBE produced, only 0.8 barrels of TBA are produced.

The long term supply curve for TBA was constructed by taking the production costs from the long term MTBE supply curve base case, and factoring in a 20% increase in operating costs. Long term TBA supply is assumed to come from areas such as Canada and the Middle East that have low-cost MTBE/TBA production economics. At the higher end of the supply curve, existing TBA production in the U.S. Gulf Coast will supply TBA to California based on the equation explained above (0.8 TBA + .34 Methanol = 1 MTBE).

Appendix A: Global Oxygenate Capacity

TABLE A-1: Global MTBE Capacity

Country/State	Company	Location	Status	Capacity (B/D)
NORTH AMERICA				
Delaware	Star Enterprises	Delaware City	Operating	2,000
New Jersey	Hess	Port Reading	Operating	1,500
Pennsylvania	Sun	Marcus Hook	Operating	2,500
Virgin Islands	Hess	St. Croix	Operating	4,000
Virginia	Amoco	Yorktown	Operating	700
Illinois	Marathon	Robinson	Operating	1,500
Indiana	Amoco	Whiting	Operating	2,800
Kentucky	Ashland	Catlettsburg	Operating	3,100
Michigan	Marathon	Detroit	Operating	1,100
Minnesota	Koch	Rosemont	Operating	1,500
Louisiana	Citgo	Lake Charles	Operating	2,700
Louisiana	Conoco	Lake Charles	Operating	1,500
Louisiana	Exxon	Baton Rouge	Operating	1,500
Louisiana	Exxon	Baton Rouge	Operating	7,000
Louisiana	Shell	Norco	Operating	6,000
Louisiana	Star Enterprises	Convent	Operating	2,500
Louisiana	Valero	Krotz Springs	Operating	2,100
Mississippi	Chevron	Pascagoula	Operating	2,400
Texas	ARCO Chemical	Channelview	Operating	28,500
Texas	Citgo	Corpus Christi	Operating	4,000
Texas	Deer Park Pet. Refinery	Deer Park	Operating	5,000
Texas	Diamond Shamrock	Sunray	Operating	2,000
Texas	Enron	LaPorte	Operating	15,000
Texas	Enterprise/Sun/Mitchell	Mt. Belvieu	Operating	16,000
Texas	Exxon	Baytown	Operating	3,000
Texas	Exxon	Baytown	Operating	7,000
Texas	Global Octane	Houston	Operating	12,500
Texas	Huntsman	Port Neches	Operating	10,000
Texas	Huntsman	Port Neches	Operating	15,000
Texas	Koch	Corpus Christi	Operating	1,100
Texas	Lyondell Petrochemical	Houston	Operating	2,000
Texas	Mobil	Beaumont	Operating	2,300
Texas	OxyChem	Chocolate Bayou	Operating	2,000
Texas	Phillips	Sweeny	Operating	3,000
Texas	Texas Petrochemical	Houston	Operating	18,000
Texas	Valero	Houston	Operating	1,500
Texas	Valero	Texas City	Operating	1,500
Texas	Valero	Corpus Christi	Operating	2,500
Texas	Valero	Corpus Christi	Operating	14,000
Wyoming	Coastal	Cheyenne	Operating	4,600
California	Atlantic Richfield	Watson	Operating	2,500
California	Chevron	El Segundo	Operating	2,000
California	Chevron	Richmond	Operating	2,000
California	Exxon	Benicia	Operating	4,000
California	Tosco	Martinez	Operating	2,200
Alberta	Neste Oy/Chevron	Edmonton	Operating	18,000
		TOTAL:	247,600	

Table A-1, con't: Global MTBE Capacity

Country	Company	Location	Status	Capacity (B/D)
LATIN AMERICA				
Argentina	Carboclor	Campana	Operating	500
Argentina	YPF	Lujan de Cuyo	Operating	1,000
Argentina	YPF	La Plata	Operating	1,000
Argentina	PGM	Ensenada	Operating	1,000
Brazil	Petrobras	Duque de Caxias	Operating	1,500
Brazil	Petrobras	Araucaria	Operating	1,709
Brazil	Petrobras	Paulinia	Operating	2,055
Brazil	Petrobras	Sao Jose dos Campos	Operating	1,514
Brazil	Petrobras	3 others	Operating	3,000
Brazil	Copene	Camacari	Operating	1,500
Brazil	Copesul	Bahia	Operating	2,000
Mexico	PEMEX	Cadereyta	Operating	800
Mexico	PEMEX	Salamanca	Operating	1,125
Mexico	PEMEX	Salina Cruz	Operating	1,500
Mexico	PEMEX	Tula	Operating	2,250
Mexico	PMI	Pajaritos	Operating	1,500
Venezuela	Corpoven	El Palito	Operating	2,675
Venezuela	Corpoven	Punta Cardon	Operating	2,175
Venezuela	Pequiven	Judibana	Operating	4,000
Venezuela	Super Octanos	Puerto La Cruz	Operating	12,500
			TOTAL	45,303
MIDDLE EAST				
Dubai	Dugas	Jebel Ali	Operating	12,500
Iran	National PC	Shiraz	Operating	1,000
Israel	Oil Ref's LTD	Ashdod	Operating	750
Israel	Dor	Haifa	Operating	1,000
Saudi Arabia	Ibn Sina	Al-Jubail	Operating	17,500
Saudi Arabia	Ibn Zahr I	Al-Jubail	Operating	12,500
Saudi Arabia	Ibn Zahr II	Al-Jubail	Operating	17,500
Saudi Arabia	SADAF	Al-Jubail	Operating	17,500
Saudi Arabia	Petromin-Mobil	Yanbu	Operating	2,500
			TOTAL	82,750
EUROPE				
Austria	OMV	Scwechat	Operating	1,600
Belgium	Fina	Antwerp	Operating	3,500
Finland	Neste Oy	Porvoo	Operating	3,000
France	Lyondell Petrochemical (formerly ARCO)	Fos-sur-mer	Operating	14,500
France	Elf	Feyzin	Operating	1,400
Germany	DEA	Heide	Operating	300
Germany	DEA	Wesseling	Operating	1,600
Germany	Erdoelfchemie	Cologne	Operating	750
Germany	Huels	Marl	Operating	3,750
Germany	OMW	Karlsruhe	Operating	3,250
Germany	VEB Pet. Komb. Schwedt	Schwedt	Operating	1,680
Greece	Hellenic Aspr. Ref.	Aspropyrgos	Operating	1,600
Greece	Motor Oils Hellas	Corinth	Operating	1,000

Table A-1, con't: Global MTBE Capacity

Country	Company	Location	Status	Capacity (B/D)
Italy	AGIP	Milazzo	Operating	1,500
Italy	AGIP	Sanazzaro	Operating	1,000
Italy	Anic	Gela	Operating	1,100
Italy	Ecofuel	Ravenna	Operating	3,250
Italy	Enichem/Anic	Gela	Operating	-
Italy	Selm	Priolo	Operating	1,000
Poland	Petrochimia Plock	Plock	Operating	1,500
Portugal	Neste Oy	Sines	Operating	1,250
Spain	Repsol	Tarragona	Operating	1,700
Spain	Repsol	Tarragona	Operating	1,300
Spain	CEPSA	Algeciras	Operating	1,000
Spain	Petronor	Bilbao	Operating	1,250
Spain	Repsol	La Coruna	Operating	1,200
Spain	Repsol	Puertollano	Operating	1,100
Spain	Repsol	Tarragona	Operating	1,300
Sweden	Statoil	Stenungsund	Operating	1,225
The Netherlands	Netherlands Refining	Europort	Operating	1,500
The Netherlands	Netherlands Refining	Rotterdam	Operating	3,500
The Netherlands	ARCO	Botlek	Operating	14,000
The Netherlands	DSM	Geleen	Operating	3,375
The Netherlands	Shell	Pemis	Operating	3,750
United Kingdom	Conoco	So. Killingholme	Operating	2,000
United Kingdom	Exxon	Fawley	Operating	3,000
United Kingdom	Lindsey Oil	Grimsby	Operating	2,500
			TOTAL	92,230
E. EUROPE / FSU				
Czech Republic	Chemopetrol	Kralupy	Operating	2,250
Hungary	Danube Petroleum Refinery	Szazholmbatta	Operating	1,250
Hungary	TIFO	Tiszauvaros	Operating	750
Lithuania	NAFTA (MNPB)	Mazeikiai	Operating	929
Romania	Astra SA	Pitesdi	Operating	852
Romania	Petromidia	Midia	Operating	852
Romania	Petrotel SA	Ploesti	Operating	510
Yugoslavia	FSK	Zrenjanin	Operating	950
Russia	Neftekhim	Nizhnekamsk	Operating	625
Russia	Moscow Oil Refinery	Moscow	Operating	1,000
Russia	Ornsk Nefteorgsintez	Omsk	Operating	1,750
Russia	Uralneftekhim	Chaikovski	Operating	2,788
Bulgaria	Naftochim	Burgas	Operating	1,859
			TOTAL	16,365
FAR EAST				
China	Hay Long	Daqing	Operating	250
China	Ningbo	Zhenhai	Operating	500
China	Quilo Petchem	Zibo	Operating	1,000
China	Shan Tong	Quilo	Operating	1,750
China	Sinopec	Dalian	Operating	250
China	Sinopec	Daqing	Operating	500

Table A-1, con't: Global MTBE Capacity

Country	Company	Location	Status	Capacity (B/D)
China	Sinopec	Maoming	Operating	1,000
China	Sinopec	Qilu	Operating	1,000
China	Sinopec	Zhenhai	Operating	1,000
China	Tan Gian	Liao	Operating	725
China	Fushin Petchem	Fushin	Operating	4,000
India	Bharat Petroleum	Bombay	Operating	1,000
Korea	Ssangyang Oil Refining	Onsan	Operating	500
Korea	Daelim	Yeochun	Operating	875
Korea	Honam Oil	Yeochun	Operating	470
Korea	Samsung/ Hyundai	Daesan	Operating	625
Korea	Yukong	Ulsan	Operating	1,200
Malaysia	Petronas	Kuantan	Operating	4,500
Malaysia	Kerteh			
Singapore	Singapore Refinery CPL	Pulau Merlimau	Operating	2,500
Singapore	PCS	Singapore	Operating	1,200
Taiwan	FPC	Kaohsiung	Operating	1,200
Taiwan	TASCO	Kaohsiung	Operating	3,150
Japan	Cosmo Oil	Sakai	Operating	1,500
Japan	Idemitsu Kosan	Chiba	Operating	2,500
Japan	Kashima Oil	Kashima	Operating	1,500
Japan	Nippon Petroleum	Negishi	Operating	1,700
Japan	Mitsui	Chiba	Operating	120
Japan	Sumitomo	Chiba	Operating	1,330
Japan	Tonen	Kawasaki	Operating	48
		TOTAL:	37,893	
		GLOBAL TOTAL:	522,141	

MTBE Projects at "Engineering/Construction" phase:

NORTH AMERICA

Trinidad & Tobago	Petroleum Co. Trinidad & Tobago Ltd	Pointe a Pierre	MTBE	929
Canada	Alberta BioClean	Ft. Saskatchewan	MTBE	19,000
			TOTAL:	19,929

LATIN AMERICA

Mexico	Petroleos Mexicanos	Cadereyta	MTBE	2,000
Brazil	Petrobras SA	Araucaria	MTBE	1,162
			TOTAL:	3,162

EUROPE

Sweden	Statoil Petrokemi SA	Stenungsund	MTBE	1,122
			TOTAL:	1,122

Table A-1, con’t: Global MTBE Capacity

FSU/ E. EUROPE				
Romania	Petrotel SA	Teleajen	MTBE	467
Romania	Petromidia SA	Navodari	MTBE	818
FSU	Permnefteorgsyntez	Perm	MTBE	4,674
FSU	Kremenchug Oil Refinery	Kremenchug	MTBE	581
Country	**Company**	**Location**	**Status**	**Capacity (B/D)**
Romania	Arpechim SA	Pitesti	MTBE	467
Slovakia	Slovnaft a.s.	Bratislava	MTBE	1,052
FSU	Achinsk Refinery	Achinsk	MTBE	510
			TOTAL:	8,569
MIDDLE EAST				
Iran	National Petrochemical Co.	Bandar Imam	MTBE	14,022
Libya	Ras Lanuf Oil & Gas Co.	Ras Lanuf	MTBE	1,098
Kuwait	Kuwait Petroleum Co.	Mina Al-Ahmadi	MTBE	1,300
			TOTAL:	16,420
FAR EAST				
Singapore	Petrochem. Corp. of Singapore Pte. Limited	Merbau	MTBE	1,192
Taiwan	Formas Petrochemical Corp.	Mai Liao	MTBE	1,168
India	Indian Oil Corp. Ltd	Gujarat	MTBE	935
Taiwan	Formas Petrochemical Corp.	Hai Fong	MTBE	4,500
			TOTAL:	7,795
TOTAL GLOBAL ADDITIONS (engineering/under construction):				56,998

MTBE Projects at "Planning" or "Unknown" phase:

NORTH AMERICA				
USA	Tosco	Martinez, CA	MTBE	2,000
			TOTAL:	2,000
LATIN AMERICA				
Chile	Refineria de Petroleo Concon SA	Concon	MTBE	697
Mexico	Productos Ecologicos SV de CV	Morelos	MTBE	17,000
Venezuela	Cerasol	Paraguana, Falcon	MTBE	11,685
Brazil	Petro. Brasiliera	Cubatao	MTBE	1,696
Brazil	Petro. Brasiliera	Mataripe	MTBE	836
			TOTAL:	31,914
EUROPE				
Belgium	Statoil	Antwerp	MTBE	16,359
Spain	Elf Atochem SA	Algeciras	MTBE	1,052
Sweden	Norsk Hydro	Lysekil	MTBE	935
			TOTAL:	18,345

Table A-1, con't: Global MTBE Capacity

Country	Company	Location	Status	Capacity (B/D)
FSU/ E. EUROPE				
Lithuania	Ministry of the Petrochemicals Industry	?	MTBE	8,179
Croatia	Ina-Industrija Nafte d.d. Zagreb	Sisak	MTBE	900
FSU	Angarsk Petrochemical Co.	Angarsk	MTBE	2,804
FSU	Tobolsk Petrochem Combine	Tobolsk	MTBE	
11,685				
Romania	Petrobrazi SA	Ploiesti	MTBE	1,870
			TOTAL:	
25,438				
MIDDLE EAST				
Qatar	Qatar Fuels Additives Co.	Umm Said	MTBE	
14,256				
Saudi Arabia	Tahseen (Alujain Corporation, Ecofuel, Neste Oy)	Yanbu	MTBE	20,910
			TOTAL:	35,165
FAR EAST				
China	Chemical Auxiliary Agent Plant	Daqing	MTBE	327
South Korea	Hanwha Chemical Corp.	Yeo-Chun	MTBE	2,337
			TOTAL:	2,664
TOTAL GLOBAL ADDITIONS (planning/unknown status):				115,527

TABLE A-2: Global Ethanol Capacity

Country	Company	Location	CAPACITY MG/Y	B/D
NORTH AMERICA				
IL	ADM (wet mill)	Decatur	210.00	13,699
IL	ADM (wet mill)	Peoria	200.00	13,046
IA	ADM (wet mill)	Cedar Rapids	200.00	13,046
IA	ADM (wet mill)	Clinton	160.00	10,437
IL	Pekin Energy Co. (wet mill)	Pekin	100.00	6,523
IN	New Energy Co. of Indiana (wet mill)	South Bend	85.00	5,545
NE	Minnesota Corn Processors (wet mill)	Columbus	80.00	5,219
NE	Cargill (wet mill)	Blair	75.00	4,892
TN	A.E. Staley	Louden	42.00	2,740
MN	Minnesota Corn Processors (wet mill)	Marshall	40.00	2,609
IA	Cargill	Eddyville	30.00	1,957
NE	High Plains Corp. (dry mill)	York	30.00	1,957
NM	Giant Industries	Portales	30.00	1,957
NE	AGP (dry mill)	Hastings	30.00	1,957
NE	Chief Ethanol (dry mill)	Hastings	30.00	1,957
KS	Midwest Grain Products	Atchinson	26.00	1,696
NE	Nebraska Energy (dry mill)	Aurora	25.00	1,631
KS	High Plains Corp.	Colwich	20.00	1,305
UT	Self Enterprises	Garland	20.00	1,305
TX	Mapco Alcohol Fuel Inc.	Cactus	20.00	1,305
IA	Hubinger Co.	Keokuk	17.50	1,142
MN	Corn Plus	Winnebago	15.00	978
MN	Chippewa Valley Ethanol Company	Benson	15.00	978
IL	Midwest Grain Products	Pekin	12.00	783
MN	Ethanol2000	Bingham Lake	11.50	750
ND	Alchem	Grafton	10.00	652
MN	Al-Corn	Claremont	10.00	652
MN	Heartland Corn Products	Winthrop	10.00	652
MN	Minnesota Energy	Buffalo Lake	10.00	652
IA	Grain Processing Corporation	Muscatine	10.00	652
KY	Parallel Products	Louisville	10.00	652
KS	Reeve Agri-Energy	Garden City	10.00	652
SD	Heartland Grain Fuel	Aberdeen	8.00	522
SD	Broin Enterprises	Scotland	7.00	457
WA	Georgia-Pacific Corp	Bellingham	7.00	457
IA	Manildra	Hamburg	7.00	457
ID	J.R. Simplot	Caldwell	4.00	261
ID	J.R. Simplot	Heyburn	3.00	196
MN	Morris Ag Energy	Morris	5.00	326
WY	Brimm Energy Inc. (Wyoming Ethanol)	Torrington	5.00	326
CA	Golden Cheese of CA	Corona	3.00	196
CA	Parallel Products	Rancho Cucamonga	2.00	130
WI	ROI	Plover	2.00	130
MN	Kraft, Inc.	Melrose	1.50	98
CO	Merrick and Co.	Golden	1.50	98
IA	Permeate Refining	Hopkinton	1.50	98
MN	Minnesota Clean Fuels	Dundas	1.20	78
KS	ESE Alchohol	Leoti	1.10	72

TABLE A-2, con't: Global Ethanol Capacity

Country	Company	Location	CAPACITY MG/Y	B/D
TX	Jonton Alcohol	Edinburg	1.10	72
WA	Pabst Brewing	Olympia	0.70	46
WI	Farm Tech USA	Spring Green	0.50	33
IL	Vienna Correctional	Vienna	0.50	33
SD	Kor Ethanol	White	0.25	16
Canada	Commercial Alcohols	Chatham (Ontario)	39.63	2,585
Canada	Mohawk Oil	Minnedosa (Manitoba)	2.64	172
		TOTAL FUEL GRADE	1,699	110,836
North American Synthetic Ethanol:				
TX	Eastman	Longview	30	1,957
IL	Millenium Petrochemicals	Tuscola	50	3,262
TX	Union Carbide	Texas City	120	7,828
		TOTAL SYNTHETIC	200	13,046
		TOTAL ETHANOL (FUEL & SYNTHETIC)	1,899	123,883
LATIN AMERICA				
Brazil	Various	Center South Region		220,581
	Various	North-Northeast Region		34,466
	Various	of which: Sao Paolo State		168,882
		TOTAL:		255,047
MIDDLE EAST				
Saudi Arabia	SABIC *(Synthetic ethanol)*		111	7,238
		TOTAL:	111	7,238
EUROPE				
Poland	Man Alchohol			
France	Sugar Beet Distilleries	7 Locations	79	5,157
France	Sugar/Alcohol Complexes	16 Locations	47	3,094
France	SODES *(synthetic ethanol)*		32	2,063
Germany	Huls *(synthetic ethanol)*		60	3,916
Germany	Erdolchemie *(synthetic ethanol)*		20	1,305
Germany	Others		40	2,611
Sweden	Örnsköldsvik	Umea		
UK	BP Chemicals *(synthetic ethanol)*	Baglan Bay	58	3,807
UK	BP Chemicals *(synthetic ethanol)*	Grangemouth	52	3,372
Italy	Wine ethanol		53	3,446

TABLE A-2, con't: Global Ethanol Capacity

Country	Company	Location	CAPACITY MG/Y	B/D
(Europe, continued)				
Spain	Wine ethanol		53	3,446
		TOTAL:	494	32,218
E. EUROPE / FSU				
Russia	Various		660	43,075
ASIA/PACIFIC				
China	Various		998	65,128
India	Various		357	23,261
Thailand			13	862
Australia	Various		15	1,000
		TOTAL:	1,384	90,250
AFRICA				
S. Africa	SASOL *(Synthetic ethanol)*	Sasolburg	106	6,892
S. Africa		Secunda		
S. Africa		Sasol "Three" Plant		
S. Africa	National Chemical Products	Germiston	7	452
S. Africa	National Chemical Producs	Umgeni	7	452
S. Africa	Illovo Sugar		7	431
		TOTAL:	126	8,227
	TOTAL GLOBAL ETHANOL CAPACITY (INCLUDES SYNTHETIC):		8,584	559,938

Corn/Biomass Ethanol Projects at "Engineering/Construction" phase:

Country	Company	Location	MG/Y	B/D
NORTH AMERICA				
MN	Central Minnesota Ethanol Coop (CMEC)	Little Falls	15	978
MT	American Agri-Technology	Great Falls	30	1,957
NE	Nebraska Nutrients Inc.	Sutherland	15	978
Canada	Commercial Alcohols	Tiverton, Ontario	6	396
Canada	Seaway Valley Farmer's Energy Cooperative Inc.	Cornwall, Ontario	15	948
		TOTAL:	81	5,258
FAR EAST				
India	Petron International	Mallanwan		514
Phillipines	Primofina Oleochemis Inc.	Jose Panganiban		653
		TOTAL:		1,167
		TOTAL GLOBAL ADDITIONS		

TABLE A-2, con't: Global Ethanol Capacity

		(engineering/under construction):		6,425

Corn/Biomass Ethanol Projects at "Planning" or "Unknown" phase:

NORTH AMERICA

IL	Adkins Energy Cooperative	Adkins	30	1,957
MN	CORN-er Stone Farmers' Cooperative	Luverne	15	978
MN	Exol Corporation - Agri Resources Co-op	Albert Lea	30	1,957
MN	RDO	Park Rapids	15	978
MN	Dawson Project	Dawson	20	1,305
MN	Renewable Oxygenates, Inc.	Madison	15	978
MN	South East Minnesota Ethanol Cooperative (SEMEC)	Preston	10	652
CA	Arkenol	Sacramento	12	783
CA	Quincy Library Group		20	1,305
CA	Gridley Project		12	783
Canada	Commercial Alcohols/ Quebec Grain Producers	Quebec	40	2,585
Canada	Commercial Alchohols	Chatham, Ontario	40	2,585
		TOTAL:	258	16,846

EUROPE

Sweden	Agroetanol AB	Norkopping	13	862
		TOTAL	13	862

		TOTAL GLOBAL ADDITIONS (planning/uknown status):		17,708

TABLE A-3: Global ETBE Capacity

Country	Plant	Location	Type	Capacity b/d
North America				
USA	Koch Refining Co.	Rosemount, MN	ETBE/MTBE	1,500
USA	Amoco Oil Co.	Yorktown, VA	ETBE/MTBE	700
USA	Amerada Hess	Virgin Islands	ETBE/MTBE	4,000
USA	ARCO Chemical	Corpus Christi, TX	ETBE/MTBE	12,000
USA	ARCO Chemical	Channelview, TX	ETBE/MTBE	28,500
USA	ARCO Products	Watson, CA	ETBE/MTBE	2,500
USA	Diamond Shamrock	Sunray, TX	ETBE/MTBE	2,000
USA	Marathon	Robinson, IL	ETBE/MTBE	1,500
			TOTAL:	52,700
Europe				
France	Elf Aquitaine	Feyzin	ETBE	1,742
Russia	Lukoil	Salavatnefteorgsintez	ETBE	3,000
Italy	Ecofuel	Ravenna	ETBE	1,800
France	Total	Dunkirk	ETBE	1,162
France	Ouest-ETBE	Gonfreville (Normandy)	ETBE	1,394
Poland	Petrochemia-MZRip	Plock	ETBE	1,859
			TOTAL:	10,957
Latin America				
Brazil	Petrobras (7 plants)	Various	MTBE/ETBE	10,000
			TOTAL:	10,000
Middle East				
Saudi Arabia	Sadaf		MTBE/ETBE	17,500
			TOTAL:	17,500
			GLOBAL TOTAL:	91,157

Projects at "Engineering/Construction" phase:

Canada	Alberta BioClean	Ft. Saskatchewan	MTBE/ETBE	19,000
France	Elf Antar		ETBE	1,800
			TOTAL:	20,800

TABLE A-4: Global TAME Capacity

Country	Company	Location	Type	Capacity
Europe				
France	Elf	Feyzin	TAME	1,250
Greece	Hellenic Aspropyrgos Refinery SA	Aspropyrgos	TAME	1,100
Italy	Praoil	Ragusa	TAME	1,200
Italy	Agip	Gela	TAME	1,234
Norway	Neste	Porvoo	TAME	1,000
UK	Lindsey Oil Refinery Ltd.	Killingholme South Humberside	TAME	1,300
			TOTAL:	7,084
Pacific				
Taiwan	Chinese Petroleum Corp.	Kaohsiung	TAME	1,500
			TOTAL:	1,500
North America				
USA	Chevron USA Products Co.	El Segundo, CA	TAME	2,600
USA	Chevron USA Products Co.	Richmond, CA	TAME	2,500
USA	Star Enterprise	Delaware City, DE	TAME	2,322
USA	Marathon Oil Co.	Robinson, IL	TAME	250
USA	Citgo Petroleum Corp.	Lake Charles, LA	TAME	3,420
USA	Star Enterprise	Convent, LA	TAME	3,150
USA	Diamond Shamrock Corp.	McKee, TX	TAME	2,140
USA	Valero Refining Co.	Corpus Christi, TX	TAME	5,000
USA	Kerr-McGee	Cotton Valley, TX	TAME	300
USA	Exxon	Baytown, TX	TAME	1,600
			TOTAL:	23,282
Latin America				
Mexico	Petroleos Mexicanos	Salina Cruz	TAME	1,396
Virgin Islands	Hess Oil Virgin Islands Corp	St. Croix	TAME	4,000
Venezuela	Corpoven SA	El Palito	MTBE/TAME	670
Argentina	YPF S.A.	La Plata	TAME	784
Venezuela	Lagoven		TAME	2,500
			TOTAL:	9,350
OTHER				
South Africa	SASOL Ltd.	Secunda	TAME	5,603
			TOTAL:	5,603
			GLOBAL TOTAL:	46,819

TABLE A-4, con’t: Global TAME Capacity

TAME Projects at "Engineering/Construction" phase:

Country	Company	Location	Type	Capacity
India	Reliance Industries Ltd	Jamnagar	TAME	4,674
Venezuela	Lagoven SA	Judibana	TAME	8,300
FSU	Atyrau Refinery	Atyrau	MTBE/TAME	3,372
			TOTAL:	16,346

TABLE A-4: Global TBA Capacity

Country	Company	Location	Type	Capacity	
Europe					
France	Lyondell Petrochemical (fomerly ARCO)	Fos-Sur-Mer	TBA	10,800	
Netherlands	ARCO Chemical	Botlek	TBA	10,400	
		TOTAL:		21,200	
North America					
USA	ARCO Chemical	Channelview, TX	TBA	22,800	
USA	Huntsman Corp	Port Neches, TX	TBA	12,000	
		TOTAL:		34,800	
FSU					
Russia	Sintezkauchuk	Togliatti	TBA/MTBE (80/20 mix)		2,400
Russia	Kauchuka	Volzhski	TBA/MTBE (80/20 mix)		1,200
		TOTAL:		3,600	
		GLOBAL TOTAL:		59,600	

Appendix B: Derivation of Breakeven Equations

There are several equations used in this report that calculate the breakeven price level for different oxygenates. They are all based on the derivation of the same equation, which first appears in Section 4.1.3.1, in determining the supply curve for ethanol delivered to California in the intermediate term (California-only ban of MTBE). This equation was developed by Mathpro, Inc.

While the equation below is used for determining the breakeven price of ethanol, it can also be used to determine the breakeven level of TAME or TBA. The co-efficients (used to determine the percentage of oxygenate needed to achieve either a 2.0 wt. % or 2.7 wt. % oxygen level in gasoline) will change, as will the values for the RVP and octane levels of each oxygenate.

Derivation of Equation for the value of ethanol in oxygenated gasoline

1. Initial identity

$$.852\ P_{B\text{-}MTBE} + .148\ P_{MTBE} = .923\ P_{B\text{-}EOH} + .077\ P_{EOH} + C_{EOH}$$

Solve for P_{EOH}

$$P_{EOH} = (.852\ P_{B\text{-}MTBE} - .923\ P_{B\text{-}EOH} + .148\ P_{MTBE} - C_{EOH}) / .077$$

Where $P_{B\text{-}MTBE}$ = Price of reformulated blendstock for oxygenate blending (RBOB) for MTBE blending
$P_{B\text{-}EOH}$ = Price of reformulated blendstock for oxygenate blending (RBOB) for Ethanol blending
P_{MTBE} = Price of MTBE
P_{EOH} = Price of ethanol
C_{EOH} = Any costs associated with ethanol blending

Co-efficients set up for ethanol and MTBE blending to achieve a 2.7 wt % oxygen level in gasoline.

2. Equations for determining change in octane in RBOBs (pool octane assumed to be 89 octane)

A. MTBE: $.852\ O_{B\text{-}MTBE} + .148\ O_{MTBE} = 89$

$$O_{B\text{-}MTBE} = (89 - .148\ O_{MTBE}) / .852$$

$$?\ O_{B\text{-}MTBE} = 89 - [(89 - .148\ O_{MTBE}) / .852]$$

$$?\ O_{B\text{-}MTBE} = 3.65$$

Where $O_{B\text{-}MTBE}$ = Octane of RBOB used for blending MTBE (assumed equal to average pool octane)
O_{MTBE} = Octane of MTBE (110 octane)
$?\ O_{B\text{-}MTBE}$ = Reduction in octane of RBOB used for blending MTBE

Co-efficients of .852 and .148 set up for MTBE blending to achieve a 2.7 wt. % oxygen level

B. Ethanol: $.923\ O_{B\text{-}EOH} + .077\ O_{EOH} = 89$

$O_{B\text{-}EOH} = (89 - .077\ O_{EOH}) / .923$

$?\ O_{B\text{-}EOH} = 89 - [\ (\ 89 - ..077\ O_{EOH}\ ) / .923\ ]$

$?\ O_{B\text{-}EOH} = 2.17$

Where $O_{B\text{-}EOH}$ = Octane of RBOB used for blending ethanol
O_{EOH} = Octane of Ethanol (115 octane)
$?\ O_{B\text{-}EOH}$ = Reduction in octane of RBOB used for blending ethanol

Co-efficients of .923 and .077 set up for ethanol blending to achieve a 2.7 wt. % oxygen level

2. Equations for determining change in RVP in RBOBs

A. MTBE: $.852\ RVP_{B\text{-}MTBE} + .148\ RVP_{MTBE} = RVP_{POOL}$

$?\ RVP_{B\text{-}MTBE} = RVP_{POOL} - [\ (RVP_{POOL} - .148\ RVP_{MTBE}\ ) / .852\ ]$

$?\ RVP_{B\text{-}MTBE} = -.174\ RVP_{POOL} + 1.39$

Where $RVP_{B\text{-}MTBE}$ = RVP of RBOB used for blending MTBE
RVP_{MTBE} = RVP of MTBE (8 RVP)
RVP_{POOL} = Pool gasoline RVP

B. Ethanol: $.923\ RVP_{B\text{-}EOH} + .077\ RVP_{EOH} = RVP_{POOL}$

$?\ RVP_{B\text{-}EOH} = RVP_{POOL} - [\ (RVP_{POOL} - .077\ RVP_{EOH}\ ) / .923\ ]$

$?\ RVP_{B\text{-}EOH} = -.083\ RVP_{POOL} + 1.50$

Where $RVP_{B\text{-}EOH}$ = RVP of RBOB used for blending ethanol
RVP_{EOH} = RVP of ethanol (18 RVP)
RVP_{POOL} = Pool gasoline RVP

3. Equations for estimating value of RBOBs

A. MTBE: $P_{B\text{-}MTBE} = P_{POOL} - (P_{OCT} * ?\ O_{B\text{-}MTBE} + P_{RVP} * ?\ RVP_{MTBE}\ )$

B. Ethanol $P_{B\text{-}EOH} = P_{POOL} - (P_{OCT} * ?\ O_{B\text{-}EOH} + P_{RVP} * ?\ RVP_{EOH}\ )$

Where $P_{B\text{-}MTBE}$ = Price of RBOB used for blending MTBE
$P_{B\text{-}EOH}$ = Price of RBOB used for blending ethanol
P_{POOL} = Price of pool gasoline
P_{OCT} = Price of octane
$?\ O_{B\text{-}MTBE}$ = Reduction in octane of RBOB used for blending MTBE
$?\ O_{B\text{-}EOH}$ = Reduction in octane of RBOB used for blending ethanol
P_{RVP} = Price of RVP

NOTE: These RBOB values are plugged into the initial identity, to solve for the price of ethanol.

Note on octane prices: In determining the breakeven level of ethanol (or other oxygenates) using the equations above, the following values for octane prices were used. In scenarios that covered oxygenates used in summer, octane was assumed to be worth 1 cent per octane number. For wintertime, octane was assumed to be worth 0.4 cents per octane number. In scenarios that covered oxygenate usage on a year-round basis, a simple average was used for the octane price (0.7 cents per octane number).

Note on RVP prices: In determining the breakeven level of ethanol (or other oxygenates) using the equations above, the following values for RVP prices were used. In scenarios that covered oxygenates used in summer, RVP was assumed to be worth -0.3 cents per RVP number (RVP value is negative in the summer because blenders need to limit RVP levels to comply with air quality regulations). For wintertime, RVP was assumed to be worth 0.3 cents per RVP number. In scenarios that covered oxygenate usage on a year-round basis, a simple average was used for the RVP value (0.0 cents per RVP number).

Derivation of Equation for the value of ethanol in regular gasoline ("gasohol")

The following equation, also developed by Mathpro, Inc., estimates the value of ethanol used as a gasoline extender in regular gasoline commonly known as gasohol. This equation is only used in Section 4.1.3.1, and calculates the price at which California blenders can bid ethanol away from blenders in States that use gasohol.

1. Initial identity:

$$P_{R\text{-}MOGAS} - P_{MOGAS} = P_{R\text{-}GASOHOL} - .9\, P_{B\text{-}EOH} - .1\, P_{EOH} - C_{EOH}$$

Solve for P_{EOH}

$$P_{EOH} = -(P_{R\text{-}MOGAS} - P_{MOGAS} - P_{R\text{-}GASOHOL} + .9\, P_{B\text{-}EOH} + C_{EOH}) / 0.1$$

Where P_{EOH} = Price of ethanol
$P_{B\text{-}EOH}$ = Price of RBOB used for blending ethanol
$P_{R\text{-}MOGAS}$ = Retail (pump) price of pool gasoline
$P_{R\text{-}GASOHOL}$ = Retail (pump) price of gasohol
P_{MOGAS} = Rack price of pool gasoline
C_{EOH} = Any costs associated with blending ethanol (assumed zero)

2. Equations for determining change in octane in ethanol RBOB (pool octane assumed to be 89 octane)

$$.9\, O_{B\text{-}EOH} + .1\, O_{EOH} = 89$$

$$O_{B\text{-}EOH} = (89 - .1\, O_{EOH}) / .9$$

$$?\, O_{B\text{-}EOH} = 89 - [\, (89 - .1\, O_{EOH}) / .9\,]$$

$$?\, O_{B\text{-}EOH} = 2.89$$

Where $O_{B\text{-}EOH}$ = Octane of RBOB used for blending ethanol
O_{EOH} = Octane of Ethanol (115 octane)
$?\, O_{B\text{-}EOH}$ = Reduction in octane of RBOB used for blending ethanol

Co-efficients of .9 and .1 set up for ethanol blending to achieve a 3.5 wt. % oxygen level commonly used in gasohol.

3. Equation for determining the retail price of gasohol

The pump price of gasohol is discounted from the pump price of regular pool gasoline since the consumer must be compensated for the fact that gasohol has a lower energy content than regular gasoline. This is due to the fact that ethanol's energy density is equal to roughly 3.55 million BTUs per barrel, whereas pool gasoline's energy density is equal to 5.25 million BTU's per barrel. Therefore, the ratio of ethanol to pool gasoline energy density is 0.68, which is used in the equation below, which states that gasohol's retail price must be equal to 90 percent of pool gasoline's retail price plus 10 percent of pool gasoline's retail price adjusted for the lower energy content due to the presence of the 10 percent ethanol blend:

$$P_{R\text{-}GASOHOL} = (.9 + .1*.68) * P_{R\text{-}MOGAS}$$

2. Equations for estimating value of ethanol RBOB:

$$P_{B\text{-}EOH} = P_{POOL} - (P_{OCT} * ?\,O_{B\text{-}EOH})$$

Where
$P_{B\text{-}EOH}$ = Price of RBOB used for blending ethanol
P_{POOL} = Price of pool gasoline
P_{OCT} = Price of octane
$?\,O_{B\text{-}EOH}$ = Reduction in octane of RBOB used for blending ethanol

3. After solving for the value of the ethanol RBOB and the value of gasohol, these inputs are plugged into the initial identity above, and solved for the price of ethanol. Throughout this study, the cost of blending with ethanol is assumed to be zero, and there is assumed to be zero consumer bias against ethanol.

Appendix C: State by state gasoline price data

	Rack	Delta		Retail	State Tax	Fed tax	Pump price	Delta
Mississippi	64.5	-	Georgia	77.10	7.7	18.3	103.10	-
Louisiana	64.6	0.1	Oklahoma	76.50	17	18.3	111.80	8.70
Georgia	64.7	0.2	South Carolina	77.20	16.75	18.3	112.25	9.15
South Carolina	65.2	0.7	Michigan	78.40	15.88	18.3	112.58	9.48
North Carolina	65.3	0.8	Missouri	78.70	17.04	18.3	114.04	10.94
Alabama	65.3	0.8	Florida	83.20	12.8	18.3	114.30	11.20
Ohio	65.6	1.1	Indiana	80.80	15.8	18.3	114.90	11.80
Arkansas	65.6	1.1	Kansas	79.00	18.03	18.3	115.33	12.23
Tennessee	65.8	1.3	Arkansas	78.70	18.6	18.3	115.60	12.50
Florida	65.8	1.3	New Jersey	87.50	10.5	18.3	116.30	13.20
Texas	65.8	1.3	Texas	79.30	20	18.3	117.60	14.50
Oklahoma	65.9	1.4	Kentucky	83.40	16.4	18.3	118.10	15.00
Virginia	65.9	1.4	Iowa	80.40	20	18.3	118.70	15.60
Indiana	66	1.5	Alabama	83.20	18	18.3	119.50	16.40
Kansas	66.6	2.1	Louisiana	81.40	20	18.3	119.70	16.60
Missouri	66.6	2.1	Tennessee	80.10	21.4	18.3	119.80	16.70
West Virginia	66.6	2.1	Virginia	83.50	18.1	18.3	119.90	16.80
Michigan	66.7	2.2	Mississippi	83.70	18	18.3	120.00	16.90
Pennsylvania	66.8	2.3	Ohio	79.90	22	18.3	120.20	17.10
Kentucky	66.9	2.4	North Carolina	80.00	22.6	18.3	120.90	17.80
Wisconsin	67.2	2.7	West Virginia	83.60	20.5	18.3	122.40	19.30
Maryland	67.3	2.8	Illinois	84.40	20.1	18.3	122.80	19.70
Illinois	67.6	3.1	Vermont	88.90	16	18.3	123.20	20.10
Delaware	68	3.5	Delaware	82.70	23	18.3	124.00	20.90
Nebraska	68.1	3.6	Nebraska	80.80	25.4	18.3	124.50	21.40
Iowa	68.2	3.7	Pennsylvania	81.30	25.82	18.3	125.42	22.32
New York	68.7	4.2	New Hampshire	87.60	19.6	18.3	125.50	22.40
N. Dakota	69.2	4.7	New York	85.40	22.8	18.3	126.50	23.40
Vermont	69.3	4.8	S. Dakota	87.30	21	18.3	126.60	23.50
S. Dakota	69.5	5.0	Wisconsin	81.70	26.8	18.3	126.80	23.70
Maine	69.8	5.3	Maine	89.50	19	18.3	126.80	23.70
New Jersey	70.2	5.7	Maryland	85.10	23.5	18.3	126.90	23.80
Massachusetts	70.2	5.7	Massachusetts	88.30	21	18.3	127.60	24.50
Minnesota	70.3	5.8	N. Dakota	89.70	20.03	18.3	128.03	24.93
Rhode Island	70.5	6.0	Minnesota	90.00	20	18.3	128.30	25.20
Connecticut	70.7	6.2	Rhode Island	84.40	29	18.3	131.70	28.60
Colorado	70.7	6.2	Connecticut	87.20	36	18.3	141.50	38.40
New Hampshire	70.9	6.4						
Washington	72.3	7.8						
New Mexico	72.4	7.9						
Arizona	72.5	8.0						
Oregon	73.7	9.2						
Montana		77.0	12.5					
Nevada	77.1	12.6						
Utah	78.6	14.1						

Appendix D: Oxygenate production cost summary

MTBE from Normal Butane via Dehydrogenation

1.0 MTBE = 1.0 N-butane + .344 methanol + $.072/gallon operating cost

MTBE from Fluid Cat Cracker C4s:

1.0 MTBE = .8 isobutylene + .344 methanol + $.036/gallon operating cost

ETBE from Fluid Cat Cracker C4s:

1.0 ETBE = .695 isoobutylene + .431 ethanol + $.046/gallon operating cost

Appendix E: Derivation of Ethanol Production costs and producers' margins

Ethanol producers face differing cost structures depending on the feedstock costs (the price of corn for over 90 percent of ethanol producers) and the price producers receive for the by-products of corn milling (distillers' dried grains, corn gluten meal, corn gluten feed, corn germ, CO_2, gypsum, etc.).

In order to determine a notional net production cost for wet milling and dry milling plants, historical data was used for the prices of corn, DDG, corn gluten meal and corn gluten corn. Due to a lack of historical data for corn germ and other minor by-products, these values were held constant. Operating and fixed costs were held constant. Ethanol producers are assumed to produce roughly 2.6 gallons of ethanol from each bushel of corn. Net production cost equals gross expenses minus gross credits.

<u>Dry Milling Operation</u> [10]

Expenses:

- Feedstock (corn) = Corn cost ($/bushel) / 2.6
- Other costs (energy, labor, depreciation, chemicals, fixed costs): .625 cents/gallon

Credits:

- Distillers' dried grains (DDG)= ((DDG cost, $/ton) / 2000 lbs) * (17.35 lbs/bushel of DDG) / 2.6
- Other byproducts = 1 cent/gallon (assumed constant)

<u>Wet Milling Operation</u>

Expenses:

- Feedstock (corn) = Corn cost ($/bushel) / 2.6
- Other costs (energy, labor, depreciation, chemicals, fixed costs): .51 cents/gallon

Credits:

- Corn gluten meal: ((gluten meal cost, $/ton) / 2000 lbs) * (2.8 lbs/bushel of corn) / 2.6
- Corn gluten feed: ((gluten feed cost, $/ton) / 2000 lbs) * (10 lbs/bushel of corn) / 2.6
- Corn germ: ((germ cost, $/ton) / 2000 lbs) * (4 lbs/bushel of corn) / 2.6
- Other byproducts = 1 cent/gallon (assumed constant)

[10] Notional cost structures for wet/dry milling producers provided by Arkenol, Inc.

Appendix F: Historical Prices for Ethanol Production

The following prices were used to construct historical ethanol net production costs using the notional formula supplied above. Historical price data for germ was not available; a constant value of $250/ton was used instead. All other prices provided by Hart's Publications.

	Ethanol Price $/gallon	Corn Price $/bu	Corn Price $/gallon	DDG ($/ton)	Gluten Meal $/ton	Gluten Feed $/ton	Germ $/ton
January-92	$1.18	$2.54	$0.98	$124.00	$270.63	$105.00	$250.00
February	$1.19	$2.62	$1.01	$125.13	$271.88	$107.50	$250.00
March	$1.20	$2.67	$1.03	$123.50	$277.50	$107.50	$250.00
April	$1.24	$2.56	$0.99	$117.13	$252.50	$108.50	$250.00
May	$1.26	$2.58	$0.99	$115.38	$245.00	$106.00	$250.00
June	$1.27	$2.63	$1.01	$115.38	$247.50	$108.50	$250.00
July	$1.28	$2.47	$0.95	$120.38	$245.63	$108.50	$250.00
August	$1.33	$2.29	$0.88	$123.00	$242.70	$108.50	$250.00
September	$1.34	$2.26	$0.87	$125.25	$264.38	$108.50	$250.00
October	$1.36	$2.17	$0.84	$125.98	$270.25	$106.50	$250.00
November	$1.38	$2.17	$0.83	$126.42	$267.38	$103.00	$250.00
December	$1.29	$2.43	$0.93	$128.44	$267.50	$106.00	$250.00
January-93	$1.19	$2.30	$0.88	$129.67	$288.33	$103.50	$250.00
February	$1.15	$2.25	$0.87	$131.50	$283.40	$96.00	$250.00
March	$1.14	$2.25	$0.86	$123.55	$296.00	$97.00	$250.00
April	$1.15	$2.29	$0.88	$112.50	$288.13	$95.00	$250.00
May	$1.18	$2.26	$0.87	$106.60	$279.88	$95.00	$250.00
June	$1.18	$2.20	$0.84	$104.88	$275.63	$95.00	$250.00
July	$1.11	$2.38	$0.92	$108.17	$294.17	$95.00	$250.00
August	$1.10	$2.46	$0.95	$111.90	$313.00	$95.00	$250.00
September	$1.10	$2.40	$0.92	$113.00	$308.13	$96.50	$250.00
October	$1.11	$2.52	$0.97	$115.70	$298.45	$95.00	$250.00
November	$1.06	$2.71	$1.04	$121.38	$304.69	$92.50	$250.00
December	$1.01	$2.79	$1.07	$124.67	$313.33	$92.50	$250.00
January-94	$1.04	$3.02	$1.16	$126.00	$314.38	$97.80	$250.00
February	$1.12	$3.03	$1.16	$127.00	$298.13	$94.50	$250.00
March	$1.11	$2.88	$1.11	$124.40	$289.50	$97.00	$250.00
April	$1.10	$2.72	$1.05	$123.00	$283.75	$98.50	$250.00
May	$1.11	$2.70	$1.04	$121.75	$265.00	$101.00	$250.00
June	$1.14	$2.82	$1.08	$119.34	$262.70	$101.00	$250.00
July	$1.18	$2.40	$0.92	$121.25	$264.38	$97.50	$250.00
August	$1.22	$2.26	$0.87	$119.38	$259.38	$102.50	$250.00
September	$1.22	$2.26	$0.87	$118.90	$240.50	$102.50	$250.00
October	$1.22	$2.16	$0.83	$120.63	$225.00	$102.50	$250.00
November	$1.24	$2.18	$0.84	$118.88	$229.38	$103.50	$250.00
December	$1.25	$2.19	$0.84	$113.13	$237.50	$107.50	$250.00
January-95	$1.22	$2.27	$0.87	$108.50	$236.25	$108.50	$250.00
February	$1.20	$2.32	$0.89	$99.88	$225.63	$108.50	$250.00
March	$1.14	$2.39	$0.92	$95.10	$218.00	$108.50	$250.00
April	$1.11	$2.48	$0.95	$93.25	$210.00	$108.50	$250.00
May	$1.12	$2.56	$0.98	$93.28	$192.50	$108.50	$250.00
June	$1.10	$2.76	$1.06	$95.20	$207.50	$107.30	$250.00
July	$1.07	$2.93	$1.13	$98.13	$211.88	$108.50	$250.00
August	$1.09	$2.86	$1.10	$100.60	$228.50	$106.50	$250.00

Appendix F, con't: Historical Prices for Ethanol Production:

	Ethanol Price $/gallon	Corn Price $/bu	Corn Price $/gallon	DDG ($/ton)	Gluten Meal $/ton	Gluten Feed $/ton	Germ $/ton
September	$1.11	$2.95	$1.13	$106.20	$244.25	$105.50	$250.00
October	$1.13	$3.11	$1.19	$123.25	$270.63	$105.50	$250.00
November	$1.17	$3.37	$1.30	$136.70	$316.80	$105.00	$250.00
December	$1.20	$3.46	$1.33	$140.33	$332.50	$107.50	$250.00
January-96	$1.25	$3.63	$1.39	$139.88	$337.50	$107.50	$250.00
February	$1.26	$3.86	$1.48	$142.60	$343.90	$107.50	$250.00
March	$1.24	$4.03	$1.55	$145.88	$342.38	$107.50	$250.00
April	$1.28	$4.58	$1.76	$152.63	$334.88	$107.50	$250.00
May	$1.37	$4.91	$1.89	$178.70	$342.40	$107.50	$250.00
June	$1.38	$4.84	$1.86	$178.88	$323.13	$107.50	$250.00
July	$1.43	$4.80	$1.84	$161.83	$307.50	$110.00	$250.00
August	$1.53	$4.65	$1.79	$151.20	$298.00	$110.00	$250.00
September	$1.54	$3.81	$1.47	$151.50	$329.38	$108.10	$250.00
October	$1.49	$2.97	$1.14	$140.20	$344.00	$108.10	$250.00
November	$1.38	$2.69	$1.03	$136.25	$340.00	$103.50	$250.00
December	$1.28	$2.69	$1.04	$140.00	$343.13	$97.50	$250.00
January-97	$1.20	$2.67	$1.03	$147.00	$336.25	$94.00	$250.00
February	$1.20	$2.76	$1.06	$147.38	$335.63	$94.00	$250.00
March	$1.19	$2.94	$1.13	$145.13	$341.25	$85.00	$250.00
April	$1.20	$2.94	$1.13	$131.60	$343.13	$85.00	$250.00
May	$1.20	$2.81	$1.08	$121.00	$352.50	$80.00	$250.00
June	$1.14	$2.67	$1.03	$115.00	$349.25	$79.00	$250.00
July	$1.15	$2.55	$0.98	$115.50	$336.25	$81.50	$250.00
August	$1.20	$2.58	$0.99	$120.50	$345.63	$81.50	$250.00
September	$1.22	$2.57	$0.99	$120.75	$356.25	$81.50	$250.00
October	$1.22	$2.62	$1.01	$118.50	$345.50	$80.50	$250.00
November	$1.22	$2.65	$1.02	$120.75	$351.25	$74.25	$250.00
December	$1.22	$2.63	$1.01	$117.75	$352.38	$78.38	$250.00
January-98	$1.19	$2.65	$1.02	$117.50	$321.88	$77.88	$250.00
February	$1.15	$2.65	$1.02	$100.88	$295.00	$76.50	$250.00
March	$1.07	$2.66	$1.02	$92.38	$273.75	$69.75	$250.00
April	$1.03	$2.50	$0.96	$84.40	$241.50	$64.70	$250.00
May	$1.04	$2.47	$0.95	$77.50	$236.25	$64.63	$250.00

Appendix G: Ethanol Producers' Historical Notional Expenses, Credits and Margins

The following are notional net production costs for wet milling ethanol producers and dry milling ethanol producers, based on the prices in Appendix F, and the formulas provided in Appendix E.

	Wet Milling Operation				**Dry Milling Operation**			
	Expense	**Credit**	**Net**	**Margin**	**Expense**	**Credit**	**Net**	**Margin**
January-92	$1.49	$0.64	$0.84	$0.34	$1.60	$0.51	$1.09	$0.09
February	$1.52	$0.65	$0.87	$0.32	$1.63	$0.52	$1.11	$0.08
March	$1.54	$0.65	$0.89	$0.32	$1.65	$0.51	$1.14	$0.06
April	$1.50	$0.64	$0.86	$0.39	$1.61	$0.49	$1.12	$0.12
May	$1.50	$0.63	$0.87	$0.39	$1.62	$0.48	$1.13	$0.13
June	$1.52	$0.64	$0.89	$0.39	$1.64	$0.48	$1.15	$0.12
July	$1.46	$0.64	$0.82	$0.46	$1.58	$0.50	$1.07	$0.21
August	$1.39	$0.64	$0.76	$0.57	$1.51	$0.51	$0.99	$0.33
September	$1.38	$0.65	$0.73	$0.61	$1.49	$0.52	$0.98	$0.37
October	$1.35	$0.65	$0.70	$0.66	$1.46	$0.52	$0.94	$0.42
November	$1.35	$0.64	$0.71	$0.67	$1.46	$0.52	$0.94	$0.44
December	$1.44	$0.64	$0.80	$0.49	$1.56	$0.53	$1.03	$0.26
January-93	$1.39	$0.65	$0.74	$0.45	$1.51	$0.53	$0.98	$0.21
February	$1.38	$0.63	$0.74	$0.41	$1.49	$0.54	$0.95	$0.20
March	$1.37	$0.64	$0.73	$0.41	$1.49	$0.51	$0.98	$0.16
April	$1.39	$0.63	$0.76	$0.39	$1.51	$0.48	$1.03	$0.12
May	$1.38	$0.63	$0.75	$0.43	$1.50	$0.46	$1.04	$0.14
June	$1.36	$0.63	$0.73	$0.45	$1.47	$0.45	$1.02	$0.16
July	$1.43	$0.64	$0.79	$0.32	$1.54	$0.46	$1.08	$0.03
August	$1.46	$0.65	$0.81	$0.29	$1.57	$0.47	$1.10	($0.00)
September	$1.43	$0.65	$0.78	$0.31	$1.55	$0.48	$1.07	$0.03
October	$1.48	$0.64	$0.84	$0.27	$1.59	$0.49	$1.11	($0.00)
November	$1.55	$0.64	$0.92	$0.14	$1.67	$0.50	$1.16	($0.10)
December	$1.58	$0.64	$0.94	$0.07	$1.70	$0.52	$1.18	($0.18)
January-94	$1.67	$0.65	$1.02	$0.02	$1.78	$0.52	$1.26	($0.22)
February	$1.68	$0.64	$1.04	$0.08	$1.79	$0.52	$1.27	($0.15)
March	$1.62	$0.64	$0.98	$0.13	$1.73	$0.52	$1.22	($0.11)
April	$1.56	$0.64	$0.92	$0.18	$1.67	$0.51	$1.16	($0.06)
May	$1.55	$0.63	$0.92	$0.19	$1.66	$0.51	$1.16	($0.05)
June	$1.60	$0.63	$0.96	$0.17	$1.71	$0.50	$1.21	($0.07)
July	$1.44	$0.63	$0.81	$0.37	$1.55	$0.50	$1.05	$0.13
August	$1.38	$0.63	$0.75	$0.48	$1.49	$0.50	$1.00	$0.23
September	$1.38	$0.62	$0.76	$0.46	$1.50	$0.50	$1.00	$0.22
October	$1.34	$0.61	$0.73	$0.49	$1.45	$0.50	$0.95	$0.27
November	$1.35	$0.62	$0.73	$0.51	$1.46	$0.50	$0.97	$0.27
December	$1.35	$0.63	$0.72	$0.53	$1.47	$0.48	$0.99	$0.26
January-95	$1.38	$0.63	$0.75	$0.47	$1.50	$0.46	$1.03	$0.19
February	$1.40	$0.63	$0.78	$0.42	$1.52	$0.43	$1.08	$0.11
March	$1.43	$0.62	$0.81	$0.33	$1.54	$0.42	$1.13	$0.01
April	$1.46	$0.62	$0.85	$0.27	$1.58	$0.41	$1.17	($0.05)
May	$1.50	$0.61	$0.89	$0.23	$1.61	$0.41	$1.20	($0.08)
June	$1.57	$0.61	$0.96	$0.14	$1.69	$0.42	$1.27	($0.17)
July	$1.64	$0.62	$1.02	$0.05	$1.75	$0.43	$1.32	($0.25)
August	$1.61	$0.62	$0.99	$0.10	$1.73	$0.44	$1.29	($0.20)
September	$1.64	$0.63	$1.01	$0.09	$1.76	$0.45	$1.30	($0.20)

Appendix G, con't: Ethanol Producers' Historical Notional Expenses, Credits and Margins

	Wet Milling Operation				Dry Milling Operation			
	Expense	**Credit**	**Net**	**Margin**	**Expense**	**Credit**	**Net**	**Margin**
October	$1.71	$0.65	$1.06	$0.07	$1.82	$0.51	$1.31	($0.17)
November	$1.81	$0.67	$1.14	$0.03	$1.92	$0.56	$1.37	($0.20)
December	$1.84	$0.68	$1.16	$0.04	$1.96	$0.57	$1.39	($0.19)
January-96	$1.91	$0.69	$1.22	$0.03	$2.02	$0.57	$1.45	($0.20)
February	$1.99	$0.69	$1.31	-$0.05	$2.11	$0.58	$1.53	($0.28)
March	$2.06	$0.69	$1.37	-$0.13	$2.17	$0.59	$1.59	($0.35)
April	$2.27	$0.68	$1.59	-$0.30	$2.38	$0.61	$1.78	($0.49)
May	$2.40	$0.69	$1.71	-$0.34	$2.51	$0.70	$1.82	($0.45)
June	$2.37	$0.68	$1.70	-$0.31	$2.49	$0.70	$1.79	($0.41)
July	$2.36	$0.67	$1.68	-$0.26	$2.47	$0.64	$1.83	($0.40)
August	$2.30	$0.67	$1.63	-$0.10	$2.41	$0.60	$1.81	($0.28)
September	$1.98	$0.68	$1.30	$0.24	$2.09	$0.61	$1.49	$0.05
October	$1.65	$0.69	$0.96	$0.53	$1.77	$0.57	$1.20	$0.29
November	$1.55	$0.68	$0.87	$0.51	$1.66	$0.55	$1.10	$0.27
December	$1.55	$0.67	$0.88	$0.40	$1.66	$0.57	$1.09	$0.19
January-97	$1.54	$0.66	$0.88	$0.32	$1.65	$0.59	$1.06	$0.13
February	$1.57	$0.66	$0.91	$0.28	$1.69	$0.59	$1.09	$0.10
March	$1.64	$0.64	$1.00	$0.20	$1.76	$0.58	$1.17	$0.02
April	$1.64	$0.65	$1.00	$0.20	$1.76	$0.54	$1.22	($0.02)
May	$1.59	$0.64	$0.95	$0.25	$1.71	$0.50	$1.20	($0.01)
June	$1.54	$0.64	$0.90	$0.24	$1.65	$0.48	$1.17	($0.03)
July	$1.49	$0.64	$0.86	$0.30	$1.61	$0.49	$1.12	$0.03
August	$1.50	$0.64	$0.86	$0.34	$1.62	$0.50	$1.11	$0.09
September	$1.50	$0.65	$0.85	$0.37	$1.61	$0.50	$1.11	$0.11
October	$1.52	$0.64	$0.88	$0.34	$1.63	$0.50	$1.14	$0.09
November	$1.53	$0.63	$0.90	$0.32	$1.64	$0.50	$1.14	$0.08
December	$1.52	$0.64	$0.89	$0.34	$1.64	$0.49	$1.14	$0.08
January-98	$1.53	$0.62	$0.91	$0.28	$1.64	$0.49	$1.15	$0.04
February	$1.53	$0.60	$0.93	$0.22	$1.64	$0.44	$1.21	($0.06)
March	$1.54	$0.58	$0.96	$0.12	$1.65	$0.41	$1.24	($0.17)
April	$1.47	$0.55	$0.92	$0.11	$1.59	$0.38	$1.20	($0.17)
May	$1.46	$0.55	$0.91	$0.12	$1.57	$0.36	$1.21	($0.18)

Average wet milling production cost: $.95/gallon
Average dry milling production cost: $1.19/gallon

Weighted ethanol producers notional net production cost (67% wet milling, 33% dry milling): $1.03/gallon

Appendix H: Corn production and cost by state

The following data is based on U.S. Department of Agriculture data. For the purposes of this study, a base of $2.60 per bushel was used as the notional weighted average U.S. price for corn ($2.60/bu is close to the average price provided by Hart Publishing in Appendix F, excluding the period of Oct 1995 -Sept 1996 when corn prices were very high). The state by state corn prices below were calculated by taking the actual (USDA) average state prices from 1988-1996, determining a differential to the weighted average US USDA price, and subtracting or adding those differentials to the base of $2.60/bushel. Production data is actual from 1996.

	Corn $/bu	**Production ('000 bu)**
SD	$ 2.37	370,000
MN	$ 2.44	868,750
ND	$ 2.44	65,520
MI	$ 2.51	216,200
IA	$ 2.54	1,718,100
WI	$ 2.54	333,000
NE	$ 2.59	1,186,900
OH	$ 2.62	305,250
IN	$ 2.63	670,350
IL	$ 2.65	1,468,800
KS	$ 2.66	357,200
MO	$ 2.69	355,100
CO	$ 2.70	133,480
AR	$ 2.73	28,750
TN	$ 2.74	78,880
KY	$ 2.75	148,800
MS	$ 2.80	61,710
MT	$ 2.80	2,055
LA	$ 2.84	65,375
WY	$ 2.85	6,150
TX	$ 2.85	201,600
MD	$ 2.85	64,635
NJ	$ 2.85	11,844
VA	$ 2.86	39,060
DE	$ 2.87	21,450
NM	$ 2.87	14,700
WV	$ 2.89	4,200
OK	$ 2.89	24,650
NC	$ 2.90	85,500
FL	$ 2.90	9,856
SC	$ 2.91	30,020
AL	$ 2.95	22,960
NY	$ 2.97	67,410
PA	$ 2.97	127,330
GA	$ 2.98	49,875
WA	$ 3.13	22,200
OR	$ 3.19	5,445
ID	$ 3.23	5,400
UT	$ 3.28	2,730
AZ	$ 3.33	7,000
CA	$ 3.34	35,200
Ontario	$ 3.22	

Appendix I: Notional Ethanol Production Costs, by state

The following table estimates the notional net cost of ethanol production in each state, based solely on differing corn costs. All other costs and byproduct credits are held constant. States are listed twice; the first listing refers to the net production cost of wet milling ethanol production, the second refers to net production costs of dry milling ethanol production. Existing production capacity for each state are listed.

State	Net ethanol Cost ($/g)	Wet milling capacity	Dry milling capacity	State	Net ethanol cost ($/g)	Wet milling Capacity	Dry Milling Capacity
SD	$0.79	-	-	IA	$1.11		2,348
MN	$0.82	2,609	-	WI	$1.11		163
ND	$0.82	-	-	ONTARIO	$1.12		2,585
MI	$0.84	-	-	ID	$1.12		-
IA	$0.85	25,440	-	NE	$1.13		7,502
WI	$0.85	-	-	UT	$1.14		1,305
NE	$0.88	10,111	-	OH	$1.14		-
OH	$0.88	-	-	IN	$1.15		-
IN	$0.89	5,545	-	IL	$1.15		815
IL	$0.90	33,268	-	KS	$1.16		3,725
KS	$0.90	-	-	AZ	$1.16		-
MO	$0.91	-	-	CA	$1.16		-
CO	$0.92	-	-	MO	$1.17		-
AR	$0.93	-	-	CO	$1.17		98
TN	$0.93	2,740	-	AR	$1.18		-
KY	$0.94	-	-	TN	$1.19		-
MS	$0.95	-	-	KY	$1.19		652
MT	$0.96	-	-	MS	$1.21		-
LA	$0.97	-	-	MT	$1.21		-
WY	$0.97	-	-	LA	$1.22		-
TX	$0.97	-	-	WY	$1.23		326
MD	$0.97	-	-	TX	$1.23		1,376
NJ	$0.97	-	-	MD	$1.23		-
VA	$0.98	-	-	NJ	$1.23		-
DE	$0.98	-	-	VA	$1.23		-
NM	$0.98	-	-	DE	$1.24		-
WV	$0.99	-	-	NM	$1.24		1,957
OK	$0.99	-	-	WV	$1.25		-
NC	$0.99	-	-	OK	$1.25		-
FL	$0.99	-	-	NC	$1.25		-
SC	$1.00	-	-	FL	$1.25		-
AL	$1.01	-	-	SC	$1.25		1,285
NY	$1.02	-	-	AL	$1.27		-
PA	$1.02	-	-	NY	$1.27		-
GA	$1.02	-	-	PA	$1.28		-
SD	$1.04	-	995	GA	$1.28		-
MN	$1.07	-	5,166	WA	$1.34		-
ND	$1.07	-	652	OR	$1.36		-
WA	$1.08	-		ID	$1.38		-
MI	$1.10	-		UT	$1.39		-
OR	$1.11	-		AZ	$1.42		-
				CA	$1.42		-

Appendix J: Calculation of long term byproduct elasticities and long term cost of ethanol

In determining the long term net production cost of ethanol, increased ethanol demand is assumed to increase the price of corn while decreasing the received price for ethanol production by-products, such as distillers' dried grains (DDG), corn gluten meal, corn gluten feed, and corn germ. Long term elasticities of supply are used to determine the effect on the long term prices of corn and corn byproducts. The long term elasticity value, "e", is defined as the change in price divided by the change in supply.

The long term elasticity of corn was supplied by the U.S. Department of Agriculture as 0.3. For the by-products, secondary source data was used to estimate elasticities. A USDA report from 1993 estimated the change in price of byproducts caused by an increase in ethanol demand (and thus an increase in corn processing). This report estimated that a change in ethanol production from 1.2 billion gallons to 5 billion gallons (a change of 3.8 billion gallons) over 7 years would cause the price of corn gluten meal to fall 7 percent, corn gluten feed to fall 12.3 percent, and distillers' dried grains to fall 4 percent. No estimation was provided for germ; an average of the price decline of corn gluten meal and corn gluten feed was assumed as a proxy (a decline of 7.7 percent). Wet milling production (which supplies byproducts of corn germ, corn gluten meal and corn gluten feed) was assumed to remain at 67 percent of national ethanol production, while dry milling production (which supplies byproduct of DDG) was assumed to remain at 33 percent of national ethanol production. Thus the base ethanol demand (1.2 billion gallons) and increase in ethanol demand (3.8 billion gallons) are multiplied by .33 for determining the change in DDG supply and .67 for determining the change in all other byproduct supplies. The elasticity calculations are provided below:

DDG (17.35 lbs per bushel at 10% moisture)

	Change in ethanol demand	In bushels of corn	In tons of DDG	
Change	1,254,000,000	482,307,692	4,184,019	
Base	396,000,000	152,307,692	1,321,269	
% Change in Supply			317%	
Change in Price			4%	
Elasticity (e = ? P / ? S)				0.0126

Gluten meal (2.88 lbs per bushel at 10% moisture)

	Change in ethanol demand	In bushels of corn	In tons of gluten meal	
Change	2,546,000,000	979,230,769	1,410,092	
Base	804,000,000	309,230,769	445,292	
% Change in Supply			317%	
Change in Price			7%	
Elasticity (e = ? P / ? S)				0.0221

Gluten feed (10 lbs per bushel at 12% moisture)

	Change in ethanol demand	In bushels of corn	In tons of gluten feed	
Change	2,546,000,000	979,230,769	4,896,154	
Base	804,000,000	309,230,769	1,546,154	
% Change in Supply			317%	
Change in Price			12.3%	
Elasticity (e = ? P / ? S)				0.0388

Appendix J, con't: Calculation of long term byproduct elasticities and long term cost of ethanol

Germ (4 lbs per bushel at 2% moisture)

	Change in ethanol demand	In bushels of corn	In tons of germ
Change	2,546,000,000	979,230,769	1,958,462
Base	804,000,000	309,230,769	618,462
% Change in Supply			317%
Change in Price			7.7%
Elasticity (e = ? P / ? S)			0.0243

In order to determine the long term cost of ethanol, the elasticities as calculated above are applied to changes in ethanol demand. The resulting net production costs for wet millers and dry millers are calculated below. The assumptions are a base U.S. corn production level of 10.1 billion bushels, a base corn price of $2.60/bushel, and base byproduct prices of : $118.5 per ton for DDGs, $283.7 per ton for corn gluten meal, $97.4 per ton for corn gluten feed, and $250 per ton for corn germ. These base price assumptions were taken from the average historical prices provided above in Appendix F, excluding the period of Oct. 1995-Sept. 1996 during which corn prices were abnormally high. Three ethanol demand levels are listed below: 10,000 b/d, 50,000 b/d and 100,000 b/d.

Total new ethanol demand (b/d):	**10,000**	**50,000**	**100,000**
In gallons/year:	153,300,000	766,500,000	1,533,000,000
Additional bushels required:	58,961,538	294,807,692	589,615,385
Elasticity effect on price			
(? P = e * ? S):	0.18%	0.88%	1.75%
Price of corn:	$2.605	$2.623	$2.646
in $/gallon of ethanol	$1.002	$1.009	$1.018
Negative change in DDG price			
(? P = e * ? S)	0.16%	0.81%	1.61%
Price of DDG	$118.31	$117.54	$116.58
in $/gallon of ethanol	$0.395	$0.392	$0.389
Negative change in gluten meal price			
(? P = e * ? S)	0.28%	1.41%	2.82%
gluten meal price	$282.90	$279.69	$275.69
in $/gallon of ethanol	$0.157	$0.155	$0.153
Negative change in gluten feed price			
(? P = e * ? S)	0.50%	2.48%	4.96%
gluten feed price	$96.91	$94.98	$92.56
in $/gallon of ethanol	$0.186	$0.183	$0.178
Negative change in germ price			
(? P = e * ? S)	0.31%	1.55%	3.11%
germ price	$249.22	$246.12	$242.23
in $/gallon of ethanol	$0.192	$0.189	$0.186

Appendix J, con't: Calculation of long term byproduct elasticities and long term cost of ethanol

Expenses (WET MILL)	$1.51	$1.52	$1.53
Credits (WET MILL)	$0.53	$0.53	$0.52
Net production cost (WET MILL)	$0.98	$0.99	$1.01
Expenses (DRY MILL)	$1.63	$1.63	$1.64
Credits (DRY MILL)	$0.39	$0.39	$0.39
Net production cost (DRY MILL)	$1.23	$1.24	$1.25
Weighted average (67% wet mill, 33% dry mill)	$1.06	$1.08	$1.09
Ethanol price minus subsidy of $.54/gallon	$0.52	$0.54	$0.55

Appendix K: Energy price assumptions

Los Angeles	
Butane	28.61
Isobutane	52.82
Propane	34.22
Conv. Unleaded	60.73
CARB Unleaded	63.72
Conv. Premium	67.71
CARB Premium	67.98
Jet	57.41
Low Sulfur Diesel	54.70
CARB Diesel	60.93
HSFO 3% $/bbl	14.59
USGC	
Unleaded	59.66
RFG Unleaded	62.22
Midgrade	61.46
RFG Midgrade	64.06
Premium	64.96
Pool gasoline	62.03
RFG Premium	67.50
Jet	54.02
High S Diesel	51.69
Low Sulfur Diesel	52.41
No. 6, 3% S, $/Bbl	14.45
MTBE	85.39
Methanol	61.22
Octane	1.06
RVP	- 0.61

International and other U.S. prices (the following prices were determined by calculating a differential based on Gulf Coast prices from the ESAI price database, and then applying that differential to the appropriate price as listed above).

Europe MTBE	81.9
New York Harbor MTBE	89.4
Mediterranean pool mogas	57.0
Northwest Europe pool mogas	56.5
Singapore pool mogas	62.1
New York Harbor mogas	63.5

Additional price assumptions:

C4 alkylate (94 octane, 7.5 RVP) 72.0

Derived as follows (derivation provided by Valero Energy Corp):
C4 alkylate = 87 octane mogas + octane value * (94-87) - RVP value * (7.5 - 7.5)

Butylene as alkylation feedstock: 69.9
Derived as follows (derivation provided by Valero Energy Corp):
1.0 butylene = 1.92 alkylate - 1.205 isobutane - 0.115 N-butane - 1.3 cents/gallon

Appendix L: Transportation cost assumptions

	Cents/gallon	Ethanol (water soluble surcharge)	
Gulf Coast to California		8	9
Midwest to California	15		
Southeast Asia to California	7	8	
Northeast Asia to California	6.5	7.5	
Brazil to Gulf Coast	5.5	6.5	
Brazil to California	9.29	10.29	
Venezuela to Gulf Coast		2.4	3.4
Venezuela to California	5.68	6.68	
Middle East to California	9.76	10.76	
Canada to California	3	4	
NW Europe to Atlantic Coast	3.29	4.29	
Med Europe to Atlantic Coast	4.14	5.14	
NW Europe to California	8.2	9.2	
Med Europe to California	8.9	9.9	
Caribbean to California	5.7	6.7	

Appendix M: Alternate Oxygenate Supply Curves

Table M-1

MTBE delivered to California
Intermediate Term
Base Case

Incremental Volume	Total Volume	Price	Delivered price to California
16,000	16,000	73.3	76.3
25,000	41,000	73.3	83.0
13,000	54,000	86.5	86.5
3,000	57,000	83.0	90.0
7,000	64,000	87.7	93.4
45,000	109,000	86.5	94.5

Table M-2

MTBE delivered to California
Intermediate Term
Base Case

Incremental Volume	Total Volume	Price	Delivered price to California
31,000	31,000	73.0	76.0
40,000	71,000	73.0	82.8
20,000	91,000	73.0	82.8
15,000	106,000	86.5	86.5
27,000	133,000	87.7	93.4

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-3

Ethanol delivered to California
Intermediate Term
Tax credit for ethanol
California ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California	Including subsidy of 54 cents/gallon
60	60	64.4	79.4	133.4
126	187	65.1	80.1	134.1
474	661	65.3	80.3	134.3
72	732	65.6	80.6	134.6
2,105	2,837	65.6	80.6	134.6
4,419	7,256	65.6	80.6	134.6
173	7,429	65.7	80.7	134.7
1,302	8,731	66.0	81.0	135.0
1,021	9,752	66.4	81.4	135.4
3,410	13,162	67.1	82.1	136.1
1,492	14,655	67.2	82.2	136.2
385	15,040	67.2	82.2	136.2
1,546	16,586	67.2	82.2	136.2
304	16,890	68.1	83.1	137.1
144	17,034	68.2	83.2	137.2
5,391	22,425	68.2	83.2	137.2
312	22,737	68.7	83.7	137.7
4,277	27,013	69.2	84.2	138.2
2,925	29,938	69.6	84.6	138.6
821	30,760	71.9	86.9	140.9
7,700	38,460	60.0	82.7	136.7
12,883	51,342	76.1	91.1	145.1
10,392	61,734	80.3	95.3	149.3
1,175	62,909	87.9	102.9	156.9
1,243	64,153	89.1	104.1	158.1
30,000	94,153	88.7	103.7	157.7
1,453	95,606	90.7	105.7	159.7
827	96,433	91.0	106.0	160.0
42	96,475	91.7	106.7	160.7
1,939	98,414	91.8	106.8	160.8

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-4

Ethanol delivered to California
Long Term
Tax credit for ethanol
California ban of MTBE

Incremental Volume	Total Volume	Price	Price to California	Including subsidy of 54 cent/gallon
10,000	10,000	52.2	67.2	121.2
10,000	20,000	52.5	67.5	121.5
10,000	30,000	52.9	67.9	121.9
10,000	40,000	53.2	68.2	122.2
10,000	50,000	53.5	68.5	122.5
10,000	60,000	53.8	68.8	122.8
10,000	70,000	54.2	69.2	123.2
10,000	80,000	54.5	69.5	123.5
10,000	90,000	54.8	69.8	123.8
10,000	100,000	55.2	70.2	124.2
10,000	110,000	55.5	70.5	124.5
10,000	120,000	55.8	70.8	124.8

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-5

Ethanol delivered to California
Intermediate Term
No tax credit for ethanol
California ban of MTBE

Incremental Volume	Total Volume	Price	Price to California
7,700	7,700	60.0	82.7
13,050	20,750	85.3	100.3
10,111	30,860	87.6	102.6
5,545	36,405	89.0	104.0
33,268	69,673	89.7	104.7
2,740	72,413	93.1	108.1
995	73,408	104.3	119.3
5,166	78,574	107.3	122.3
652	79,226	107.3	122.3
2,348	81,575	110.8	125.8
163	81,738	110.8	125.8
2,585	84,323	112.0	127.0
7,502	91,824	113.1	128.1
1,305	93,129	113.9	128.9
815	93,944	115.2	130.2
3,725	97,669	115.6	130.6
98	97,767	117.2	132.2
652	98,419	119.1	134.1
326	98,745	122.8	137.8
1,376	100,122	122.9	137.9
1,957	102,079	123.7	138.7

Table M-6

Ethanol delivered to California
Long Term
No tax credit for ethanol
California ban of MTBE

Incremental volume	Total Volume	Price	Price to California
7,700	7,700	60.0	82.7
8,423	16,123	78.8	93.8
11,032	27,155	81.8	96.8
25,440	52,595	85.3	100.3
18,534	71,128	87.6	102.6
5,545	76,673	89.0	104.0
33,268	109,941	89.7	104.7

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-7

ETBE delivered to California
Intermediate Term
Tax credit for ethanol
California ban of MTBE

Incremental Volume	Total volume of ETBE	Volume of ethanol feedstock	Ethanol input	ETBE Cost	Price to California	Minus Subsidy
5,000	5,000	2,150	134.6	111.1	114.1	90.9
5,000	10,000	4,300	134.6	111.1	114.1	90.9
5,000	15,000	6,450	134.6	111.1	114.1	90.9
5,000	20,000	8,600	135.0	111.2	114.2	91.0
5,000	25,000	10,750	129.1	108.7	117.7	94.5
5,000	30,000	12,900	129.1	108.7	117.7	94.5
5,000	35,000	15,050	129.2	108.8	117.8	94.6
5,000	40,000	17,200	130.2	109.2	118.2	95.0
5,000	45,000	19,350	130.2	109.2	118.2	95.0
5,000	50,000	21,500	130.2	109.2	118.2	95.0
5,000	55,000	23,650	131.2	109.6	118.6	95.4
5,000	60,000	25,800	131.2	109.6	118.6	95.4
5,000	65,000	27,950	131.6	109.8	118.8	95.6
5,000	70,000	30,100	133.9	110.8	119.8	96.6
5,000	75,000	32,250	136.0	111.7	120.7	97.5
5,000	80,000	34,400	136.0	111.7	120.7	97.5
5,000	85,000	36,550	136.0	111.7	120.7	97.5
5,000	90,000	38,700	138.1	112.6	121.6	98.4
5,000	95,000	40,850	138.1	112.6	121.6	98.4
5,000	100,000	43,000	138.1	112.6	121.6	98.4
5,000	105,000	45,150	138.1	112.6	121.6	98.4
5,000	110,000	47,300	150.7	118.0	127.0	103.8
5,000	115,000	49,450	150.9	118.1	127.1	103.9
5,000	120,000	51,600	152.4	118.7	127.7	104.5
5,000	125,000	53,750	152.4	118.7	127.7	104.5
5,000	130,000	55,900	156.5	120.5	129.5	106.3
5,000	135,000	58,050	156.5	120.5	129.5	106.3
5,000	140,000	60,200	156.5	120.5	129.5	106.3
5,000	145,000	62,350	156.5	120.5	129.5	106.3
5,000	150,000	64,500	156.5	120.5	129.5	106.3
5,000	155,000	66,650	156.5	120.5	129.5	106.3
5,000	160,000	68,800	156.5	120.5	129.5	106.3
5,000	165,000	70,950	159.6	121.8	130.8	107.6
5,000	170,000	73,100	159.7	121.9	130.9	107.7
5,000	175,000	75,250	159.7	121.9	130.9	107.7
5,000	180,000	77,400	159.9	122.0	131.0	107.8

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-8

ETBE delivered to California
Long Term
Tax credit for ethanol
California ban of MTBE

Incremental Volume of ETBE	Total Volume of ETBE	Ethanol Feedstock	Ethanol Input Price	ETBE Price	Delivered Price to California	Less Tax credit
5,000	5,000	2,150	121.2	105.3	108.3	85.1
5,000	10,000	4,300	121.2	105.3	105.3	82.1
5,000	15,000	6,450	121.2	105.3	108.3	85.1
5,000	20,000	8,600	121.2	105.3	108.3	85.1
5,000	25,000	10,750	121.5	105.5	108.5	85.3
5,000	30,000	12,900	121.5	105.5	108.5	85.3
5,000	35,000	15,050	121.5	105.5	108.5	85.3
5,000	40,000	17,200	114.5	102.4	111.4	88.2
5,000	45,000	19,350	114.5	102.4	111.4	88.2
5,000	50,000	21,500	114.9	102.6	111.6	88.4
5,000	55,000	23,650	114.9	102.6	111.6	88.4
5,000	60,000	25,800	114.9	102.6	111.6	88.4
5,000	65,000	27,950	114.9	102.6	111.6	88.4
5,000	70,000	30,100	114.9	102.6	111.6	88.4
5,000	75,000	32,250	114.9	102.6	111.6	88.4
5,000	80,000	34,400	114.9	102.6	111.6	88.4
5,000	85,000	36,550	114.9	102.6	111.6	88.4
5,000	90,000	38,700	114.9	102.6	111.6	88.4
5,000	95,000	40,850	115.2	102.7	111.7	88.5
5,000	100,000	43,000	115.2	102.7	111.7	88.5
5,000	105,000	45,150	115.2	102.7	111.7	88.5
5,000	110,000	47,300	115.2	102.7	111.7	88.5
5,000	115,000	49,450	115.2	102.7	111.7	88.5
5,000	120,000	51,600	115.8	103.0	112.0	88.8
5,000	125,000	53,750	115.8	103.0	112.0	88.8
5,000	130,000	55,900	115.8	103.0	112.0	88.8
5,000	135,000	58,050	115.8	103.0	112.0	88.8
5,000	140,000	60,200	116.2	103.1	112.1	88.9
5,000	145,000	62,350	116.2	103.1	112.1	88.9
5,000	150,000	64,500	116.2	103.1	112.1	88.9
5,000	155,000	66,650	116.2	103.1	112.1	88.9
5,000	160,000	68,800	116.2	103.1	112.1	88.9
5,000	165,000	70,950	116.5	103.3	112.3	89.1
5,000	170,000	73,100	116.5	103.3	112.3	89.1
5,000	175,000	75,250	116.5	103.3	112.3	89.1
5,000	180,000	77,400	116.5	103.3	112.3	89.1

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-9

ETBE delivered to California
Intermediate Term
No tax credit for ethanol
California ban of MTBE

Incremental Volume of ETBE	Total Volume of ETBE	Ethanol Feedstock	Ethanol Input Price	ETBE Price	Delivered Price to California
5,000	2,150	5,000	82.7	88.8	91.8
5,000	4,300	10,000	82.7	88.8	91.8
5,000	6,450	15,000	82.7	88.8	91.8
5,000	8,600	20,000	93.3	93.3	102.3
5,000	10,750	25,000	93.3	93.3	102.3
5,000	12,900	30,000	93.3	93.3	102.3
5,000	15,050	35,000	93.3	93.3	102.3
5,000	17,200	40,000	93.3	93.3	102.3
5,000	19,350	45,000	93.3	93.3	102.3
5,000	21,500	50,000	95.6	94.3	103.3
5,000	23,650	55,000	95.6	94.3	103.3
5,000	25,800	60,000	95.6	94.3	103.3
5,000	27,950	65,000	95.6	94.3	103.3
5,000	30,100	70,000	95.6	94.3	103.3
5,000	32,250	75,000	97.0	94.9	103.9
5,000	34,400	80,000	97.0	94.9	103.9
5,000	36,550	85,000	97.7	95.2	104.2
5,000	38,700	90,000	97.7	95.2	104.2
5,000	40,850	95,000	97.7	95.2	104.2
5,000	43,000	100,000	97.7	95.2	104.2
5,000	45,150	105,000	97.7	95.2	104.2
5,000	47,300	110,000	97.7	95.2	104.2
5,000	49,450	115,000	97.7	95.2	104.2
5,000	51,600	120,000	97.7	95.2	104.2
5,000	53,750	125,000	97.7	95.2	104.2
5,000	55,900	130,000	97.7	95.2	104.2
5,000	58,050	135,000	97.7	95.2	104.2
5,000	60,200	140,000	97.7	95.2	104.2
5,000	62,350	145,000	97.7	95.2	104.2
5,000	64,500	150,000	97.7	95.2	104.2
5,000	66,650	155,000	97.7	95.2	104.2
5,000	68,800	160,000	97.7	95.2	104.2
5,000	70,950	165,000	101.1	96.6	105.6
5,000	73,100	170,000	112.3	101.5	110.5

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-10

ETBE delivered to California
Long Term
No tax credit for ethanol
California ban of MTBE

Incremental Volume of ETBE	Total Volume of ETBE	Ethanol Feedstock	Ethanol Input Price	ETBE Price	Delivered Price to California
10,000	10,000	4,300	82.7	88.8	91.8
10,000	20,000	8,600	93.8	93.5	96.5
10,000	30,000	12,900	93.8	93.5	96.5
10,000	40,000	17,200	89.8	91.8	100.8
10,000	50,000	21,500	89.8	91.8	100.8
10,000	60,000	25,800	89.8	91.8	100.8
10,000	70,000	30,100	93.3	93.3	102.3
10,000	80,000	34,400	93.3	93.3	102.3
10,000	90,000	38,700	93.3	93.3	102.3
10,000	100,000	43,000	93.3	93.3	102.3
10,000	110,000	47,300	93.3	93.3	102.3
10,000	120,000	51,600	93.3	93.3	102.3
10,000	130,000	55,900	95.6	94.3	103.3
10,000	140,000	60,200	95.6	94.3	103.3
10,000	150,000	64,500	95.6	94.3	103.3
10,000	160,000	68,800	95.6	94.3	103.3
10,000	170,000	73,100	97.0	94.9	103.9

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-11

TAME delivered to California
Intermediate Term
California ban of MTBE

Incremental Volume of TAME	Total Volume of TAME	Price	Price to California
5,100	5,100	85.3	95.3
2,300	7,400	77.2	95.4
4,784	12,184	77.3	96.2
9,350	21,534	80.9	96.6
15,610	37,144	80.9	98.9
1,500	38,644	84.5	101.5
2,572	41,216	84.6	104.6
5,603	46,819	84.7	104.7

Table M-12

TBA delivered to California
Intermediate Term
California ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California
14,400	14,400	80.6	83.6
54,600	69,000	84.1	92.1
10,400	79,400	76.4	94.6
10,800	90,200	76.4	95.3
34,800	125,000	80.7	98.7

Table M-13

TBA delivered to California
Long Term
California ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California
24,800	24,800	75.1	78.1
32,000	56,800	75.1	84.8
16,000	72,800	75.1	84.8
12,000	84,800	87.4	87.4
34,800	119,600	80.7	88.7

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-14

Ethanol delivered to California
Intermediate Term
Tax credit for ethanol
U.S. ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California	Price w/ subsidy
592	592	86.4	101.4	155.4
184	776	86.8	101.8	155.8
1,258	2,034	88.1	103.1	157.1
45	2,079	88.2	103.2	157.2
1,703	3,782	91.0	106.0	160.0
6,159	9,941	92.0	107.0	161.0
2,799	12,740	92.2	107.2	161.2
2,576	15,316	93.6	108.6	162.6
16,711	32,027	95.2	110.2	164.2
1,279	33,306	98.3	113.3	167.3
5,069	38,375	98.5	113.5	167.5
2,034	40,410	98.6	113.6	167.6
9,727	50,137	98.9	113.9	167.9
15,108	65,245	98.9	113.9	167.9
1,828	67,073	99.2	114.2	168.2
10,961	78,034	100.2	115.2	169.2
1,406	79,441	100.8	115.8	169.8
9,676	89,117	101.1	116.1	170.1
6,755	95,872	101.4	116.4	170.4
2,502	98,374	101.5	116.5	170.5
1,771	100,145	101.7	116.7	170.7
5,081	105,226	101.8	116.8	170.8
1,431	106,657	102.5	117.5	171.5
7,387	114,044	102.6	117.6	171.6

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-15

Ethanol delivered to California
Long Term
Tax credit for ethanol
U.S. ban of MTBE

Incremental Volume	Total Volume	Price	Price to California	Price with 54 c/g subsidy
5,000	5,000	55.5	70.5	124.5
5,000	10,000	55.8	70.8	124.8
5,000	15,000	56.1	71.1	125.1
5,000	20,000	56.5	71.5	125.5
5,000	25,000	56.8	71.8	125.8
5,000	30,000	57.1	72.1	126.1
5,000	35,000	57.5	72.5	126.5
5,000	40,000	57.8	72.8	126.8
5,000	45,000	58.1	73.1	127.1
5,000	50,000	58.4	73.4	127.4
5,000	55,000	58.8	73.8	127.8
5,000	60,000	59.1	74.1	128.1
5,000	65,000	59.4	74.4	128.4
5,000	70,000	59.8	74.8	128.8
5,000	75,000	60.1	75.1	129.1
5,000	80,000	60.4	75.4	129.4
5,000	85,000	60.7	75.7	129.7
5,000	90,000	61.1	76.1	130.1
5,000	95,000	61.4	76.4	130.4
5,000	100,000	61.7	76.7	130.7

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-16
Ethanol delivered to California
Intermediate Term
No tax credit for ethanol
U.S. ban of MTBE

Total Volume	Incremental volume	Price	Delivered price to California
7,700	7,700	60.0	82.7
20,750	13,050	85.3	100.3
30,860	10,111	87.6	102.6
36,405	5,545	89.0	104.0
69,673	33,268	89.7	104.7
72,413	2,740	93.1	108.1
73,408	995	104.3	119.3
78,574	5,166	107.3	122.3
79,226	652	107.3	122.3
81,575	2,348	110.8	125.8
81,738	163	110.8	125.8
84,323	2,585	112.0	127.0
91,824	7,502	113.1	128.1
93,129	1,305	113.9	128.9
93,944	815	115.2	130.2
97,669	3,725	115.6	130.6
97,767	98	117.2	132.2
98,419	652	119.1	134.1
98,745	326	122.8	137.8
100,122	1,376	122.9	137.9
102,079	1,957	123.7	138.7
105,026	2,948	133.8	148.8
107,928	2,902	137.7	152.7
110,700	2,771	141.8	156.8

Table M-17
Ethanol delivered to California
Long Term
No tax credit for ethanol
U.S. ban of MTBE

Incremental volume	Total volume	Price	Delivered price to California
7,700	7,700	60.0	82.7
8,423	16,123	78.8	93.8
11,032	27,155	81.8	96.8
25,440	52,595	85.3	100.3
18,534	71,128	87.6	102.6
5,545	76,673	89.0	104.0
33,268	109,941	89.7	104.7

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-18

ETBE delivered to California
Intermediate Term
Tax credit for ethanol
U.S. ban of MTBE

Incremental Volume of ETBE	Total volume of ETBE	Ethanol feedstock volume	Ethanol cost	ETBE price	ETBE delivered price to California	Less subsidy
5,000	5,000	2,150	160.0	122.2	122.2	99.0
5,000	10,000	4,300	161.0	122.6	122.6	99.4
5,000	15,000	6,450	161.0	122.6	125.6	102.4
5,000	20,000	8,600	161.0	122.6	125.6	102.4
5,000	25,000	10,750	161.2	122.7	125.7	102.5
5,000	30,000	12,900	161.2	122.7	125.7	102.5
5,000	35,000	15,050	155.6	120.2	129.2	106.0
5,000	40,000	17,200	157.2	121.0	130.0	106.8
5,000	45,000	19,350	157.2	121.0	130.0	106.8
5,000	50,000	21,500	157.2	121.0	130.0	106.8
5,000	55,000	23,650	157.2	121.0	130.0	106.8
5,000	60,000	25,800	157.2	121.0	130.0	106.8
5,000	65,000	27,950	157.2	121.0	130.0	106.8
5,000	70,000	30,100	157.2	121.0	130.0	106.8
5,000	75,000	32,250	160.3	122.3	131.3	108.1
5,000	80,000	34,400	160.3	122.3	131.3	108.1
5,000	85,000	36,550	160.3	122.3	131.3	108.1
5,000	90,000	38,700	160.6	122.4	131.4	108.2
5,000	95,000	40,850	160.9	122.5	131.5	108.3
5,000	100,000	43,000	160.9	122.5	131.5	108.3
5,000	105,000	45,150	160.9	122.5	131.5	108.3
5,000	110,000	47,300	160.9	122.5	131.5	108.3
5,000	115,000	49,450	160.9	122.5	131.5	108.3
5,000	120,000	51,600	160.9	122.5	131.5	108.3
5,000	125,000	53,750	160.9	122.5	131.5	108.3
5,000	130,000	55,900	160.9	122.5	131.5	108.3
5,000	135,000	58,050	160.9	122.5	131.5	108.3
5,000	140,000	60,200	160.9	122.5	131.5	108.3
5,000	145,000	62,350	160.9	122.5	131.5	108.3
5,000	150,000	64,500	160.9	122.5	131.5	108.3
5,000	155,000	66,650	161.2	122.7	131.7	108.5
5,000	160,000	68,800	162.2	123.1	132.1	108.9
5,000	165,000	70,950	162.2	123.1	132.1	108.9
5,000	170,000	73,100	162.2	123.1	132.1	108.9
5,000	175,000	75,250	162.2	123.1	132.1	108.9
5,000	180,000	77,400	162.2	123.1	132.1	108.9
5,000	185,000	79,550	163.1	123.5	132.5	109.3

Appendix M, con’t: Alternate Oxygenate Supply Curves

Table M-19

ETBE delivered to California
Long Term
Tax credit for ethanol
U.S. ban of MTBE

Incremental Volume of ETBE	Total volume of ETBE	Ethanol feedstock volume	Ethanol cost	ETBE price	ETBE delivered price to California	Less subsidy
10,000	10,000	4,300	124.5	106.7	106.7	83.5
10,000	20,000	8,600	124.8	106.9	109.9	86.7
10,000	30,000	12,900	125.1	107.0	110.0	86.8
10,000	40,000	17,200	125.5	107.1	110.1	86.9
10,000	50,000	21,500	118.8	104.3	113.3	90.1
10,000	60,000	25,800	119.1	104.4	113.4	90.2
10,000	70,000	30,100	119.5	104.6	113.6	90.4
10,000	80,000	34,400	119.5	104.6	113.6	90.4
10,000	90,000	38,700	119.8	104.7	113.7	90.5
10,000	100,000	43,000	120.1	104.8	113.8	90.6
10,000	110,000	47,300	120.4	105.0	114.0	90.8
10,000	120,000	51,600	120.8	105.1	114.1	90.9
10,000	130,000	55,900	121.1	105.3	114.3	91.1
10,000	140,000	60,200	121.4	105.4	114.4	91.2
10,000	150,000	64,500	121.4	105.4	114.4	91.2
10,000	160,000	68,800	121.8	105.5	114.5	91.3
10,000	170,000	73,100	122.1	105.7	114.7	91.5
10,000	180,000	77,400	122.4	105.8	114.8	91.6

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-20

ETBE delivered to California
Intermediate Term
No tax credit for ethanol
U.S. ban of MTBE

Incremental Volume of ETBE	Total Volume of ETBE	Ethanol Feedstock	Ethanol Input Price	ETBE Price	Delivered Price to California
5,000	5,000	2,150	82.7	88.8	88.8
5,000	10,000	4,300	82.7	88.8	88.8
5,000	15,000	6,450	97.7	95.2	98.2
5,000	20,000	8,600	100.3	96.3	99.3
5,000	25,000	10,750	100.3	96.3	99.3
5,000	30,000	12,900	100.3	96.3	99.3
5,000	35,000	15,050	93.3	93.3	102.3
5,000	40,000	17,200	93.3	93.3	102.3
5,000	45,000	19,350	93.3	93.3	102.3
5,000	50,000	21,500	95.6	94.3	103.3
5,000	55,000	23,650	95.6	94.3	103.3
5,000	60,000	25,800	95.6	94.3	103.3
5,000	65,000	27,950	95.6	94.3	103.3
5,000	70,000	30,100	95.6	94.3	103.3
5,000	75,000	32,250	97.0	94.9	103.9
5,000	80,000	34,400	97.0	94.9	103.9
5,000	85,000	36,550	97.7	95.2	104.2
5,000	90,000	38,700	97.7	95.2	104.2
5,000	95,000	40,850	97.7	95.2	104.2
5,000	100,000	43,000	97.7	95.2	104.2
5,000	105,000	45,150	97.7	95.2	104.2
5,000	110,000	47,300	97.7	95.2	104.2
5,000	115,000	49,450	97.7	95.2	104.2
5,000	120,000	51,600	97.7	95.2	104.2
5,000	125,000	53,750	97.7	95.2	104.2
5,000	130,000	55,900	97.7	95.2	104.2
5,000	135,000	58,050	97.7	95.2	104.2
5,000	140,000	60,200	97.7	95.2	104.2
5,000	145,000	62,350	97.7	95.2	104.2
5,000	150,000	64,500	97.7	95.2	104.2
5,000	155,000	66,650	97.7	95.2	104.2
5,000	160,000	68,800	97.7	95.2	104.2
5,000	165,000	70,950	101.1	96.6	105.6
5,000	170,000	73,100	112.3	101.5	110.5
5,000	175,000	75,250	115.3	102.8	111.8
5,000	180,000	77,400	115.3	102.8	111.8

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-21

ETBE delivered to California
Long Term
No tax credit for ethanol
U.S. ban of MTBE

Incremental Volume of ETBE	Total Volume of ETBE	Ethanol Feedstock	Ethanol Input Price	ETBE Price	Delivered Price to
10,000	10,000	4,300	82.7	88.8	88.8
10,000	20,000	8,600	93.8	93.5	96.5
10,000	30,000	12,900	93.8	93.5	96.5
10,000	40,000	17,200	96.8	94.8	97.8
10,000	50,000	21,500	89.8	91.8	100.8
10,000	60,000	25,800	89.8	91.8	100.8
10,000	70,000	30,100	93.3	93.3	102.3
10,000	80,000	34,400	93.3	93.3	102.3
10,000	90,000	38,700	93.3	93.3	102.3
10,000	100,000	43,000	93.3	93.3	102.3
10,000	110,000	47,300	93.3	93.3	102.3
10,000	120,000	51,600	93.3	93.3	102.3
10,000	130,000	55,900	95.6	94.3	103.3
10,000	140,000	60,200	95.6	94.3	103.3
10,000	150,000	64,500	95.6	94.3	103.3
10,000	160,000	68,800	95.6	94.3	103.3
10,000	170,000	73,100	97.0	94.9	103.9
10,000	180,000	77,400	97.7	95.2	104.2

Table M-22

TAME delivered to California
Intermediate Term
U.S. ban of MTBE

Incremental Volume of TAME	Total Volume of TAME	Price	Price to California
5,100	5,100	78.2	78.2
2,300	7,400	78.2	96.4
4,784	12,184	78.7	97.6
9,350	21,534	78.7	94.4
15,610	37,144	80.1	98.1
1,500	38,644	80.1	97.1
2,572	41,216	80.1	100.1
5,603	46,819	80.1	100.1

Appendix M, con't: Alternate Oxygenate Supply Curves

Table M-23

TBA delivered to California
Intermediate Term
U.S. ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California
10,160	10,160	77.4	77.4
14,400	24,560	79.5	82.5
10,000	34,560	79.5	87.5
10,000	44,560	79.5	87.5
10,000	54,560	81.6	89.6
10,000	64,560	81.9	89.9
10,000	74,560	81.9	89.9
10,000	84,560	81.9	89.9
10,000	94,560	81.9	89.9
10,000	104,560	82.7	90.7
10,000	114,560	82.7	90.7
10,000	124,560	83.3	91.3
10,000	134,560	83.3	91.3

Table M-24

TBA delivered to California
Long Term
U.S. ban of MTBE

Incremental Volume	Total Volume	Price	Delivered price to California
24,800	24,800	75.1	78.1
32,000	56,800	75.1	84.8
16,000	72,800	75.1	84.8
12,000	84,800	87.4	87.4
34,800	119,600	80.7	88.7